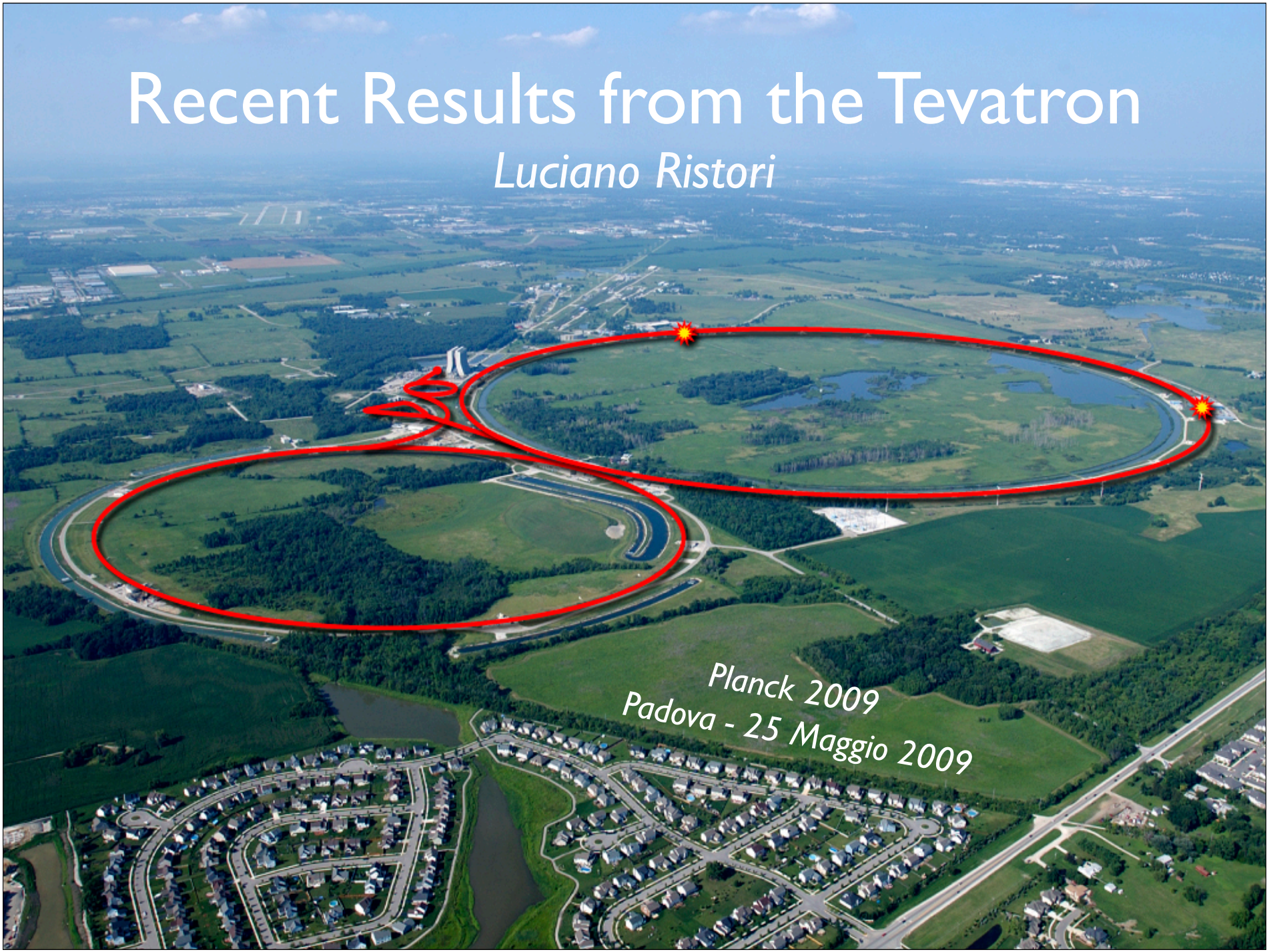
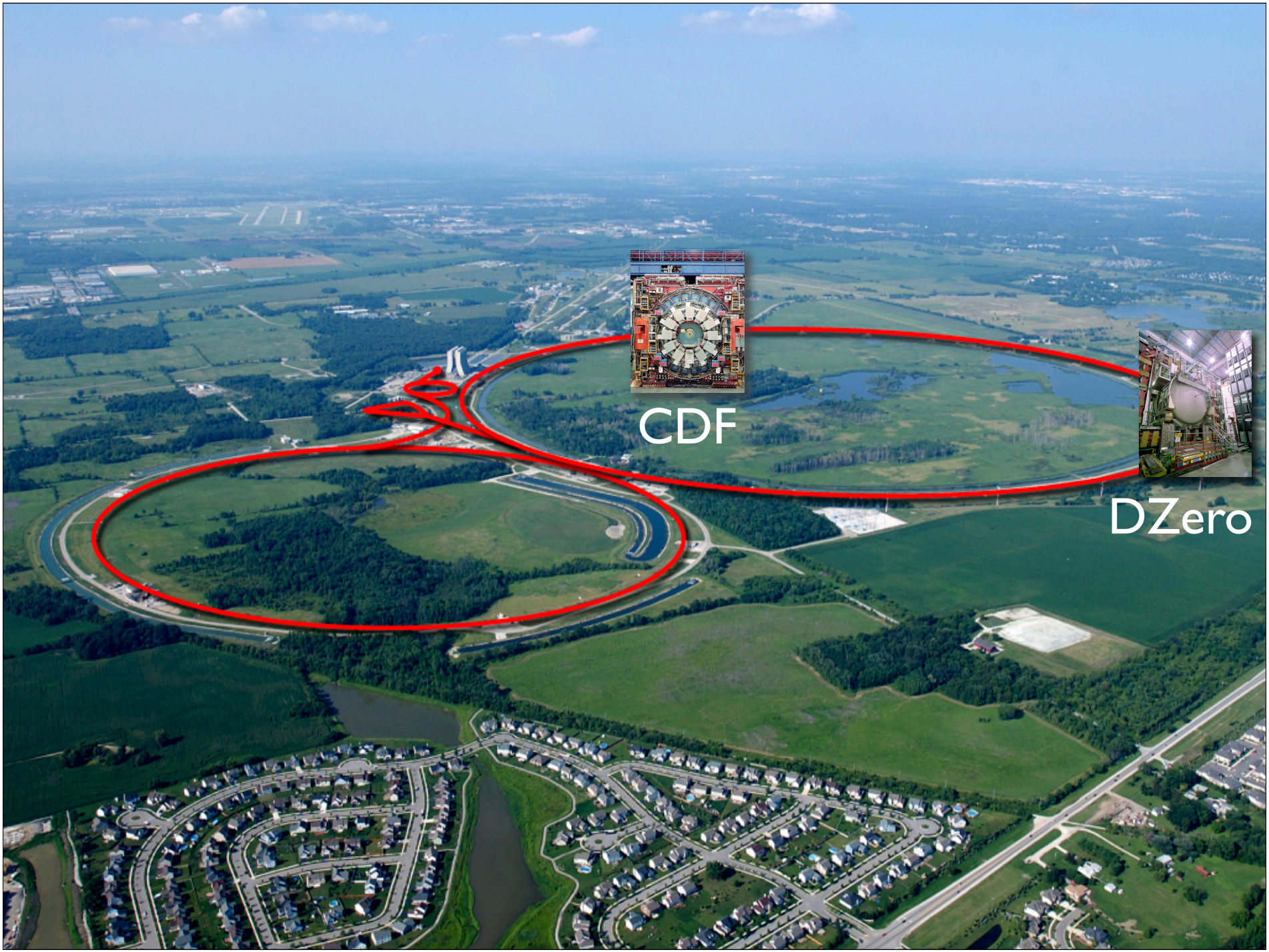
Recent Results from the Tevatron

Luciano Ristori

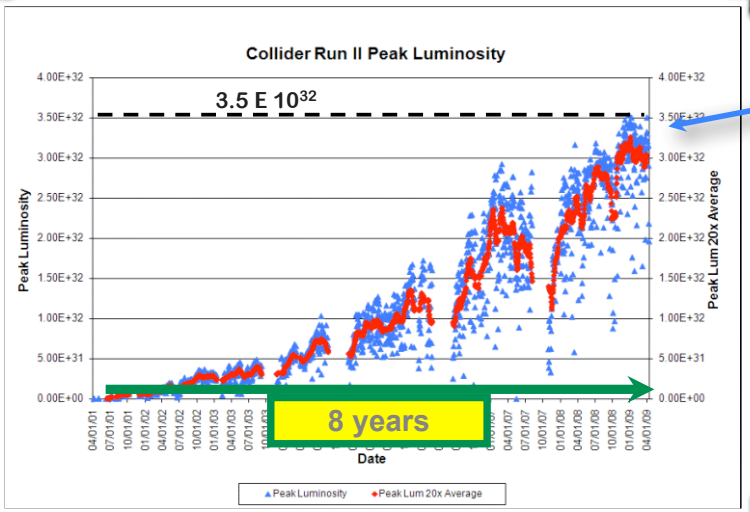


Planck 2009
Padova - 25 Maggio 2009

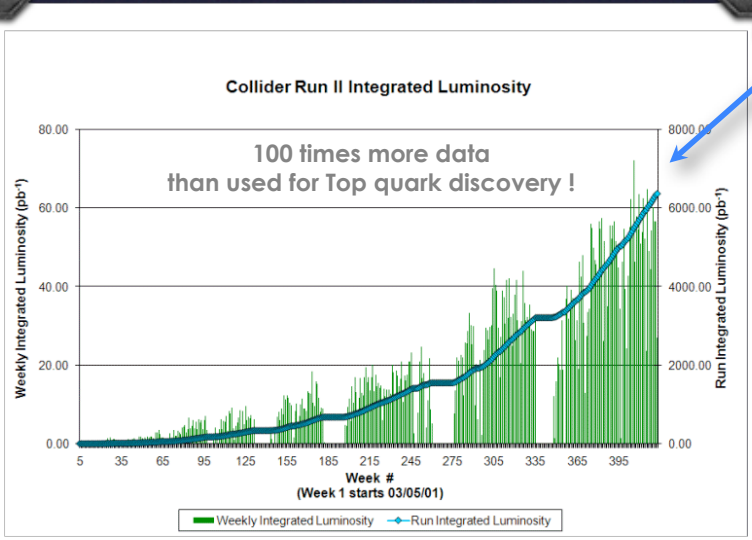

CDF
DZero

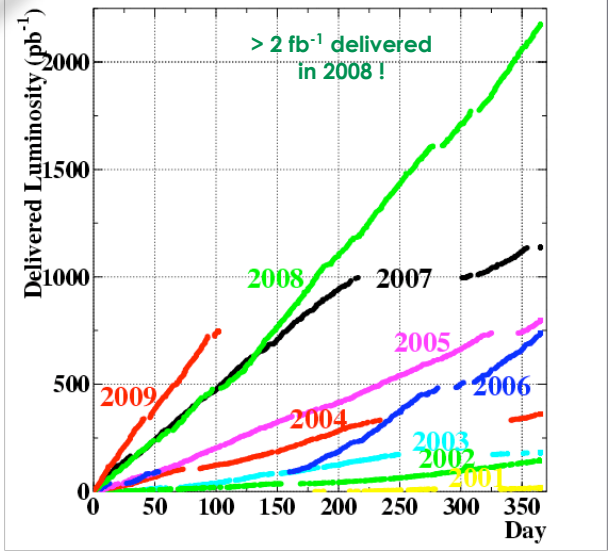

CDF
♦ 15 Countries
♦ 63 Institutions
♦ 602 authors
D0
♦ 18 Countries
♦ 90 Institutions
♦ 533 Authors
The
CDF
and
DØ
Collaborations

Run 2 Luminosity Progress



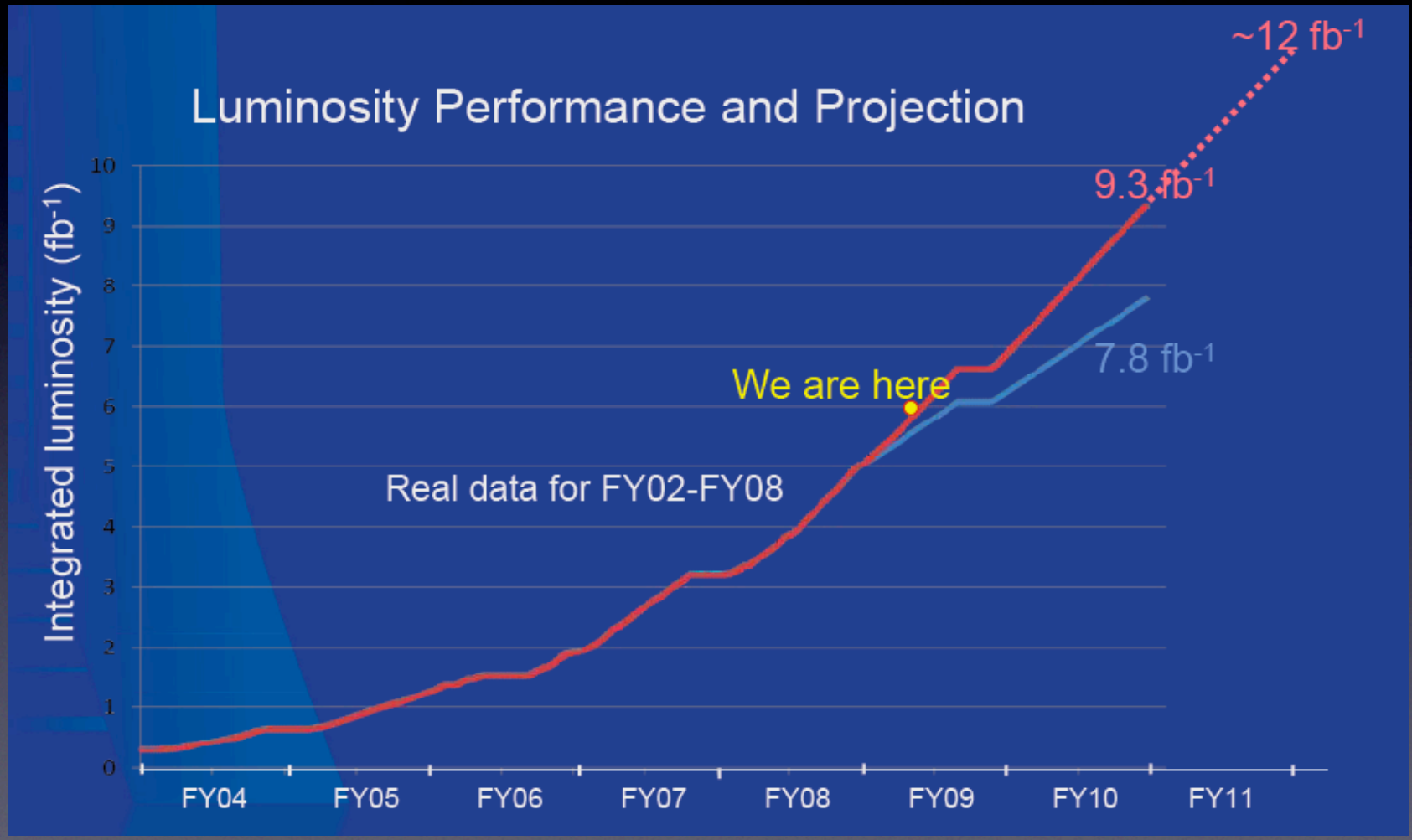
Record peak inst. luminosity
$3.6\ E\ 10^{32}\ cm^{-2}\ s^{-1}$
Record luminosity/week
$73\ pb^{-1}$
Record luminosity/month
$250\ pb^{-1}$
Total Luminosity delivered
$6.5\ fb^{-1}$

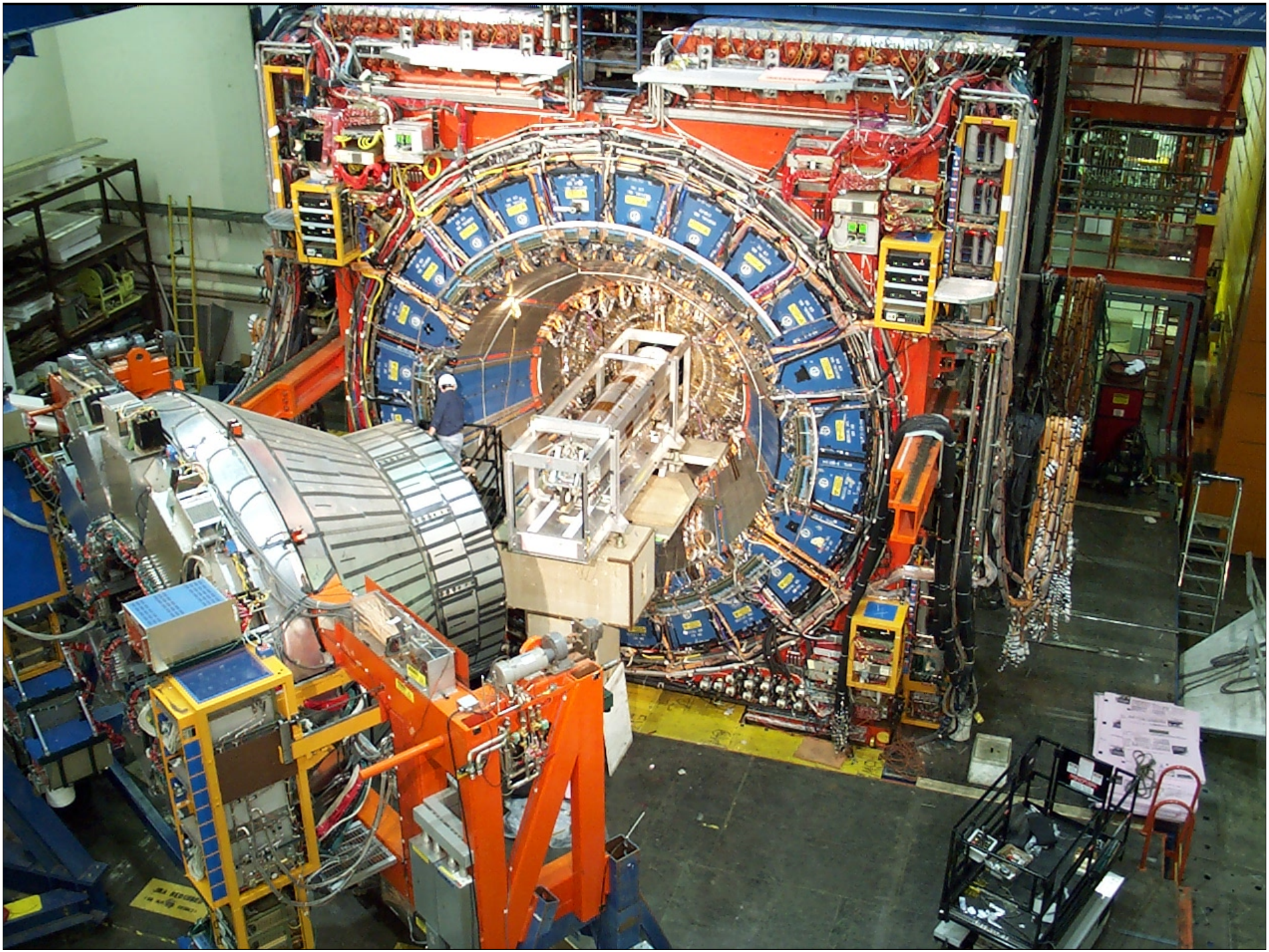


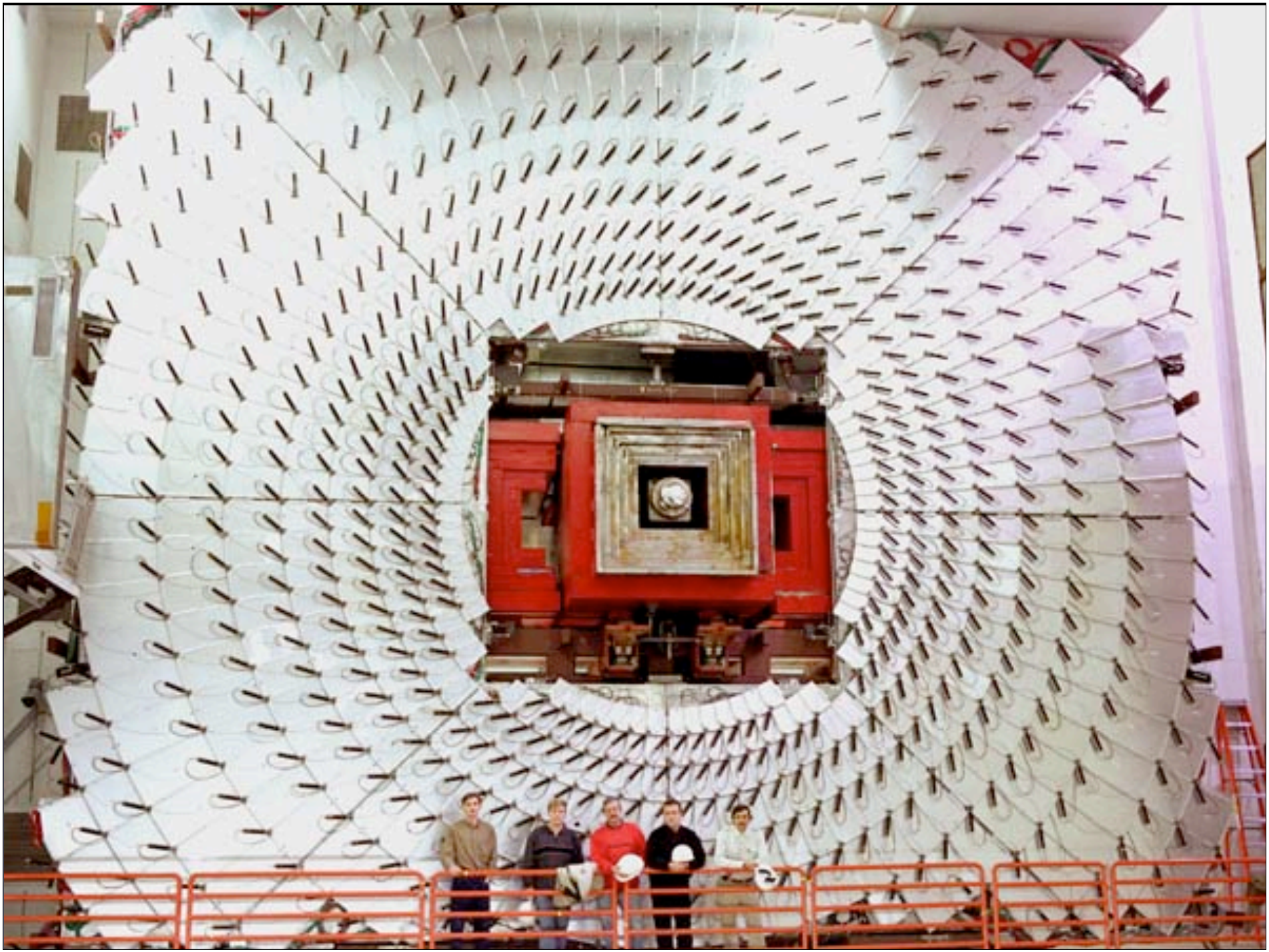


Projected TeVatron Performance

Pier Oddone - March 20, 2009

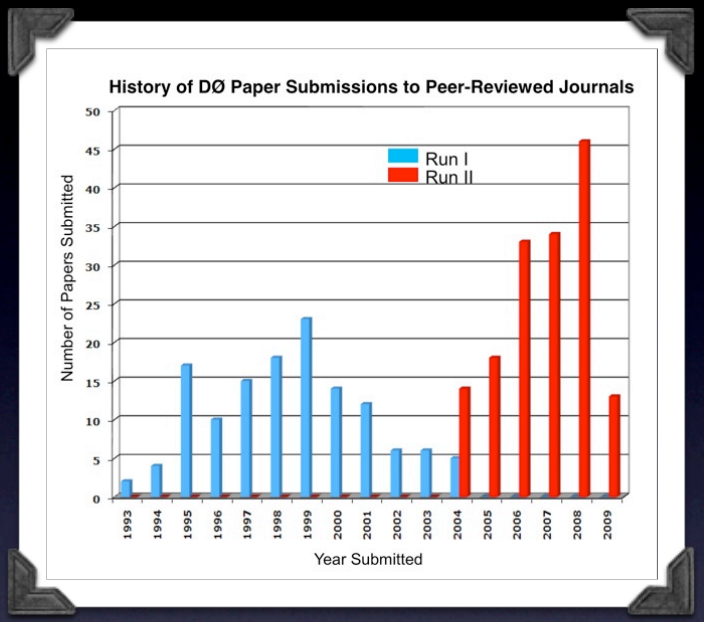


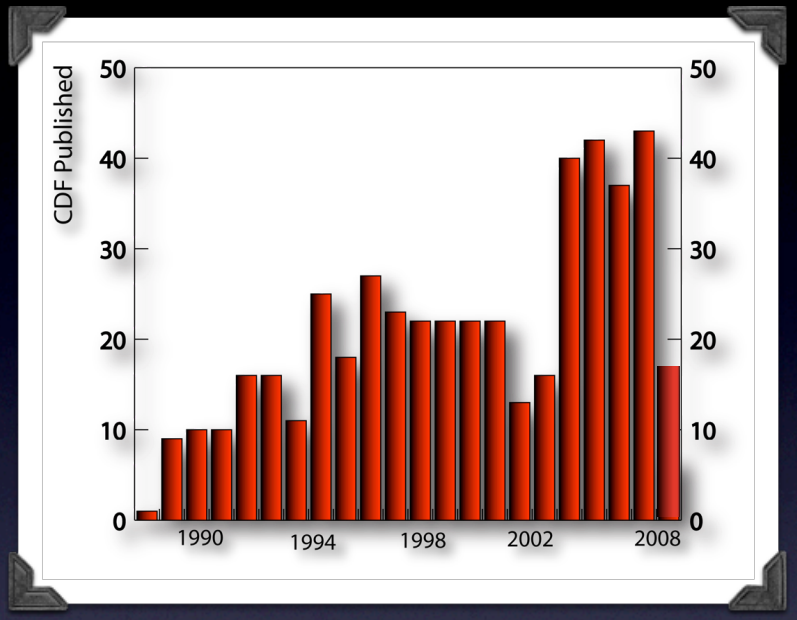




- Tevatron performance is excellent
- Detectors are well understood
- Smooth data taking
- Smooth data processing
- Sophisticated analysis techniques

Tevatron Physics Impact





- Nearly 100 journal publications last year alone
- About 60 Ph.D.’s / year over the last few years
- About 3500 physicists have participated on the CDF and D0 experiments

New Results Since Summer 08

public web pages

http://www-cdf.fnal.gov/physics/W09CDFResults.html

http://www-d0.fnal.gov/Run2Physics/W09D0Results.html

Top Physics

Analysis	Luminosity	More Information
CDF top quark mass combination	3.2 fb^{-1}	WebPage
Tevatron top quark mass combination	3.6 fb^{-1}	WebPage
Observation of single top quark production	3.2 fb^{-1}	WebPage
Combined search for single top quark production	3.2 fb^{-1}	WebPage
Search for single top quark production MET+jets	2.1 fb^{-1}	WebPage
Search for single top quark production using a neural network	3.2 fb^{-1}	WebPage
Search for single top quark production using a boosted decision tree	3.2 fb^{-1}	WebPage
Search for single top quark production using a multivariate likilihood function	3.2 fb^{-1}	WebPage
Search for single top quark production using a matrix element discriminant	3.2 fb^{-1}	WebPage
Measurement of the forward-backward asymmetry in top pair production	3.2 fb^{-1}	WebPage
Measurement of ttbar Cross Section in lepton+jets using a neural network	2.8 fb^{-1}	WebPage
Measurement of ttbar Cross Section in lepton+jets using a secondary vertex tag	2.7 fb^{-1}	WebPage
Ratio of ttbar/Z Cross Sections in lepton+jets using a neural network	2.8 fb^{-1}	WebPage
Measurement of ttbar/Z Cross Sections in lepton+jets using a secondary vertex tag	2.7 fb^{-1}	WebPage
Measurement of t-tbar differential cross section	2.7 fb^{-1}	WebPage
Measurement of the top quark mass using a template-based method	3.2 fb^{-1}	WebPage
Measurement of top mass in lepton + jet events using soft muon tags	2.0 fb^{-1}	WebPage
Measurement of top mass in lepton + jet events using lepton p_T	2.7 fb^{-1}	WebPage
Measurement of top mass in lepton + jet events using a matrix element method	3.2 fb^{-1}	WebPage
Measurement of top mass in lepton + jet and dilepton events using a template method	3.0 fb^{-1}	WebPage
Measurement of top mass in the all-hadronic mode using a template method	2.9 fb^{-1}	WebPage

Higgs Physics

Analysis	Luminosity	More Information
CDF Higgs Combination	3.0 fb^{-1}	WebPage
Search for VH→ MET+ bb Events	2.1 fb^{-1}	WebPage
Search for WH→ lν bb Events	2.7 fb^{-1}	WebPage
Search for ZH→ll bb Events	2.7 fb^{-1}	WebPage
Search for WH→ WWW	2.7 fb^{-1}	WebPage

QCD Results

Analysis	Luminosity	More Information
Exclusive Charmonium Production	1.5 fb^{-1}	
Kγ Distributions of Particles in Jets	0.8 fb^{-1}	
Search for Exclusive Z Production	2.2 fb^{-1}	
Measurement of Inclusive Photon Production	2.5 fb^{-1}	
Measurement of Z+jets Production	2.5 fb^{-1}	WebPage
Search for Quark Substructure in Dijet Angular Distributions	1.1 fb^{-1}	WebPage

Exotic Physics

Analysis	Luminosity	More Information
Search for High-Mass Resonances with Lepton Flavor Violating Decays	1 fb^{-1}	WebPage
Search for Gluino-Mediated Sbottom Production	2.5 fb^{-1}	WebPage
Search for Fermiophobic Higgs Boson Decaying to Diphotons	3.0 fb^{-1}	WebPage
Search for Anomalous Diphoton + X Production	2.0 fb^{-1}	WebPage
Search for a Heavy Resonance Decaying to ZZ	2.9 fb^{-1}	WebPage
Search for GMSB SUSY MOdels in the γγ+MET Final State	2.0 fb^{-1}	WebPage

Bottom Physics

Analysis	Luminosity	More Information
Evidence for a Narrow Structure in the J/ψ φ mass spectrum in B J/ψ φ K decays	2.7 fb^{-1}	WebPage
A Precision Determination of the mass of X(3872) using J/Ψ π π Decays	2.4 fb^{-1}	WebPage

Electroweak Physics

Analysis	Luminosity	More Information
Limits on Anomalous Triple Gauge Couplings using WZ events	1.9 fb^{-1}	WebPage

≈ 100 new results

Bottom Physics

Analysis	Luminosity	More Information
A search for excess dimuon production in the radial region (1.6<10) cm at the D0 experiment	1.0 fb^{-1}	Web page
A new expected upper limit on B(B_s->mu^+mu^-) using 5 fb-1 of Run II data	5.0 fb^{-1}	Web page
Evidence for the decay B0s->D(s*)D(s*) and a measurement of DeltaGamma_s*CP/Gamma_s	2.8 fb^{-1}	Publication
Measurement of the angular and lifetime parameters of the decays Bd to J/psi K*0 and Bs to J/psi phi	2.8 fb^{-1}	Publication
Observation of the doubly strange b baryon Omega_b*-	1.3 fb^{-1}	Publication

Electroweak Physics

Analysis	Luminosity	More Information
Measurement of the W boson mass with 1 fb-1 of D0 Run II data	1.0 fb^{-1}	Web page
Measurement of WW production cross section with dilepton final states in pp(bar) collisions at sqrt(s)=1.96 TeV and limits on anomalous trilinear gauge couplings	1.0 fb^{-1}	Web page
Measurement of the Zγ →νγ cross section and limits on anomalous ZZγ and Zγγ couplings	3.6 fb^{-1}	Publication
Evidence of WW+WZ production with lepton+jets final states in pp(bar) collisions	1.1 fb^{-1}	Publication
Measurement of sigma(ppbar -> Z + X) Br(Z -> tau+tau-)	1.0 fb^{-1}	Publication

New Phenomena

Analysis	Luminosity	More Information
ident search for New Physics at D0 in final states containing leptons	1.0 fb^{-1}	Web page
s sneutrino particles in the electron plus muon final state at D0	4.1 fb^{-1}	Web page
ction of charginos and neutralinos in the trilepton final state usin 2.3 fb-1 of data	2.3 fb^{-1}	Publication
he lightest scalar top quark in events with two leptons in ppbar collisions	1.0 fb^{-1}	Publication
Search for charged massive stable particles with the D0 detector	1.1 fb^{-1}	Publication

Analysis	Luminosity	More Information
Combined Upper Limits on Standard Model Higgs Boson Production from the D0 Experiment in 0.9-4.2 fb-1	4.2 fb^{-1}	Web page
Combined CDF and Dzero Upper Limits on Standard Model Higgs-Boson Production with up to 4.2 fb-1 of data	4.2 fb^{-1}	Web page
Search for the standard model Higgs boson in the tt(bar)H->tt(bar)bb(bar) channel	2.1 fb^{-1}	Web page
Search for associated Higgs boson production with like sign leptons in pp(bar) collisions at sqrt(s)=1.96 TeV	3.6 fb^{-1}	Web page
Search for ZH->eebb and ZH->mumubb production in 4.2 fb-1 of data with the D0 detector in pp(bar) collisions at sqrt(s)=1.96 TeV	4.2 fb^{-1}	Web page
Search for a Fermiophobic Higgs boson in the diphoton final state using 4.2 fb-1 of D0 data	4.2 fb^{-1}	Web page
Search for the standard model Higgs boson in tau final states	1.0 fb^{-1}	Web page
Search for Higgs boson production in dilepton plus missing energy final states with 3.0-4.2 fb-1 of pp(bar) collisions at sqrt(s)=1.96 TeV	3.0-4.2 fb-1	Web page
Search for h->aa->4mu or h->aa->2mu2tau with 3.7 fb-1 at D0 in Run II	3.7 fb^{-1}	Web page
Search for the standard model Higgs boson in γγ final states at D0 with L=4.2 fb-1	4.2 fb^{-1}	Web page
Search for WH associated production using a combined Neural Network and Matrix Element approach	2.7 fb^{-1}	Web page
Search for the standard model Higgs boson in diphoton final states	2.7 fb^{-1}	Publication
Search for neutral Higgs bosons at high tan beta in the b(h/H/A) to btau+tau- channel	0.3 fb^{-1}	Publication
A search for associated W and Higgs boson production	1.0 fb^{-1}	Publication
A search for the standard model Higgs boson in the missing energy and acoplanar b-jet topology	0.9 fb^{-1}	Publication
Search for neutral Higgs bosons in multi-b-jet events in ppbar collisions	0.9 fb^{-1}	Publication

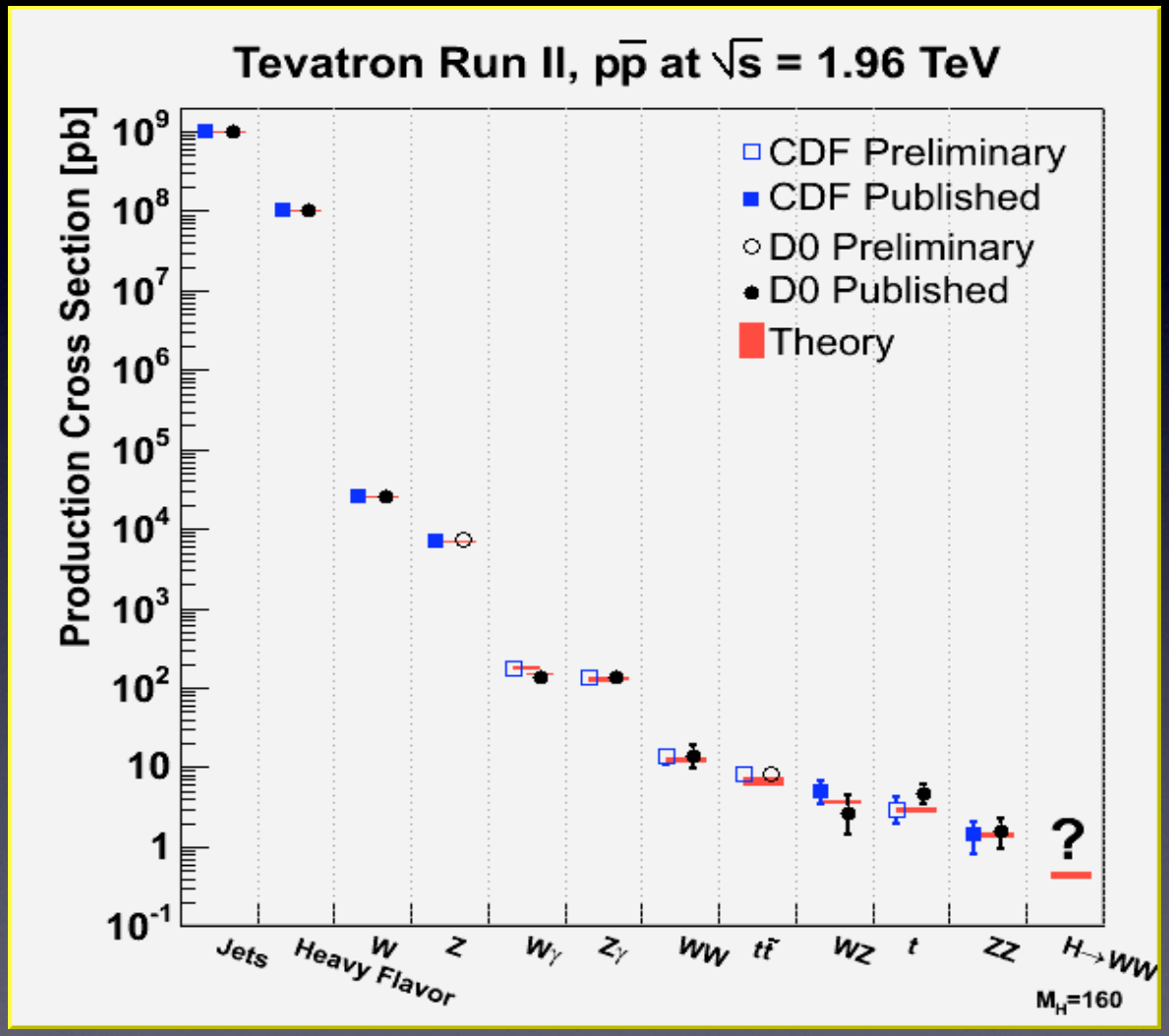
QCD Results

Analysis	Luminosity	More Information
Measurement of Z/gamma*+jet+X angular distributions in ppbar collisions at sqrt(s)=1.96 GeV	1.0 fb^{-1}	Web Page
Measurement of differential cross sections of Z/gamma*+jets+X events in pp(bar) collisions at sqrt(s)=1.96 TeV	1.0 fb^{-1}	Publication
Measurement of gamma+b+X and gamma+c+X production cross sections	1.0 fb^{-1}	Publication
Measurement of the differential Z/gamma*+jet+X cross sections	1.0 fb^{-1}	Publication

Top Physics

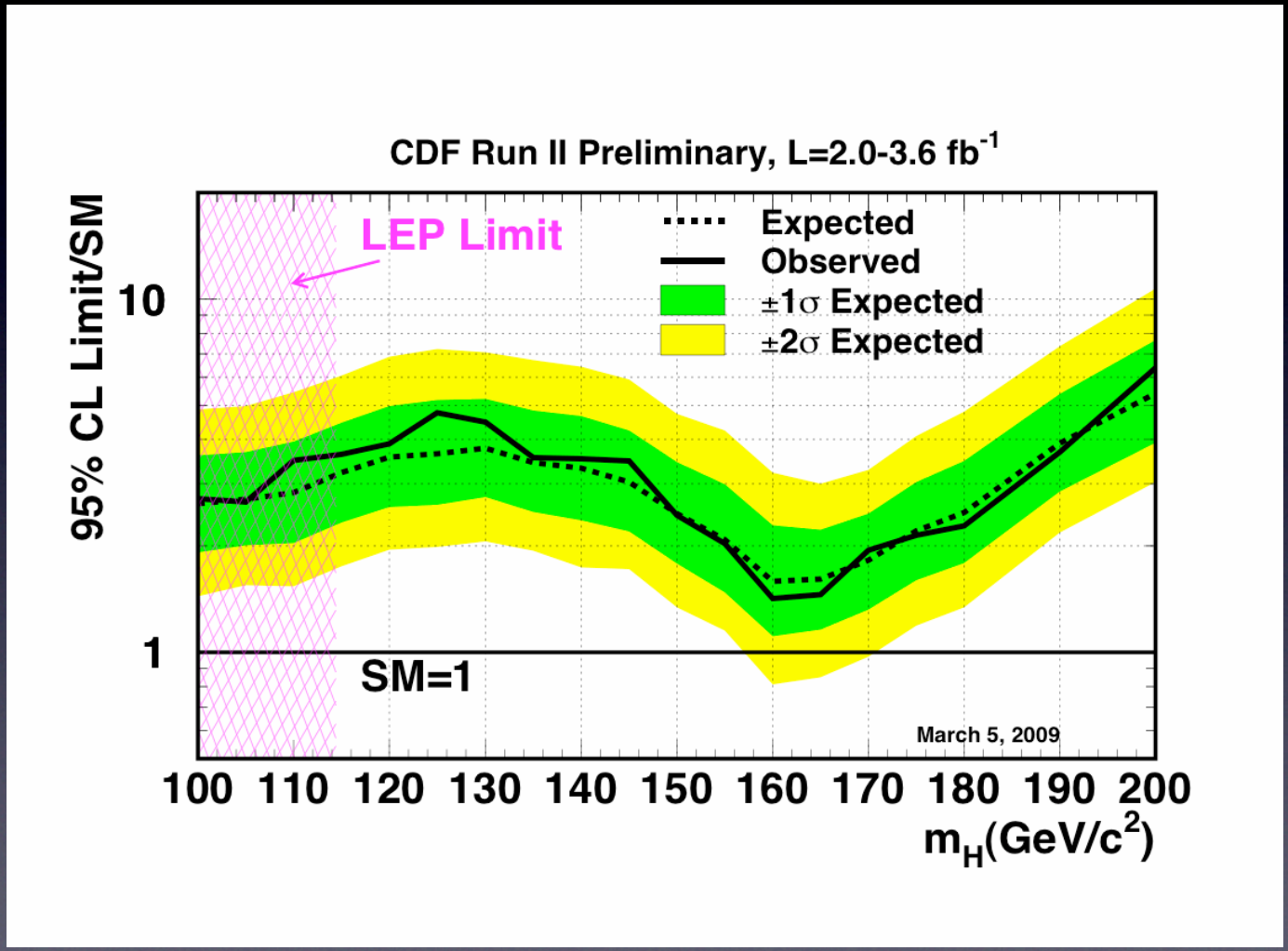
Analysis	Luminosity	More Information
Search for tt(bar) resonances in the lepton+jets final state in pp(bar) collisions at sqrt(s)=1.96 TeV	3.6 fb^{-1}	Web page
Search for the standard model Higgs boson in the tt(bar)H->tt(bar)bb(bar) channel	2.1 fb^{-1}	Web page
Combination and interpretation of tt(bar) cross section measurements with the D0 detector	1.0 fb^{-1}	Web page
Combination of CDF and D0 results on the mass of the top quark	0.1-3.6 fb^{-1}	Web page
Combination of the D0 top quark mass measurements	0.1-3.6 fb^{-1}	Web page
Measurement of the top quark mass in the electron+muon channel using the Matrix Element method with 3.6 fb-1	3.6 fb^{-1}	Web page
Measurement of the top quark mass in the lepton+jets channel using the matrix element method on 3.6 fb-1 of D0 Run II data	3.6 fb^{-1}	Web page
Measurement of anomalous top quark couplings	2.7 fb^{-1}	Web page
Observation of single top production	2.3 fb^{-1}	Publication
Measurement of the ttbar cross section and top quark mass extraction using dilepton events	1.0 fb^{-1}	Publication
Search for admixture of scalar top quarks in the tt(bar) lepton+jets final states	0.9 fb^{-1}	Publication
Search for anomalous top quark couplings with the D0 detector	1.0 fb^{-1}	Publication
Search for charged Higgs bosons decaying to top and bottom quarks in ppbar collisions	0.9 fb^{-1}	Publication

10 orders of magnitude

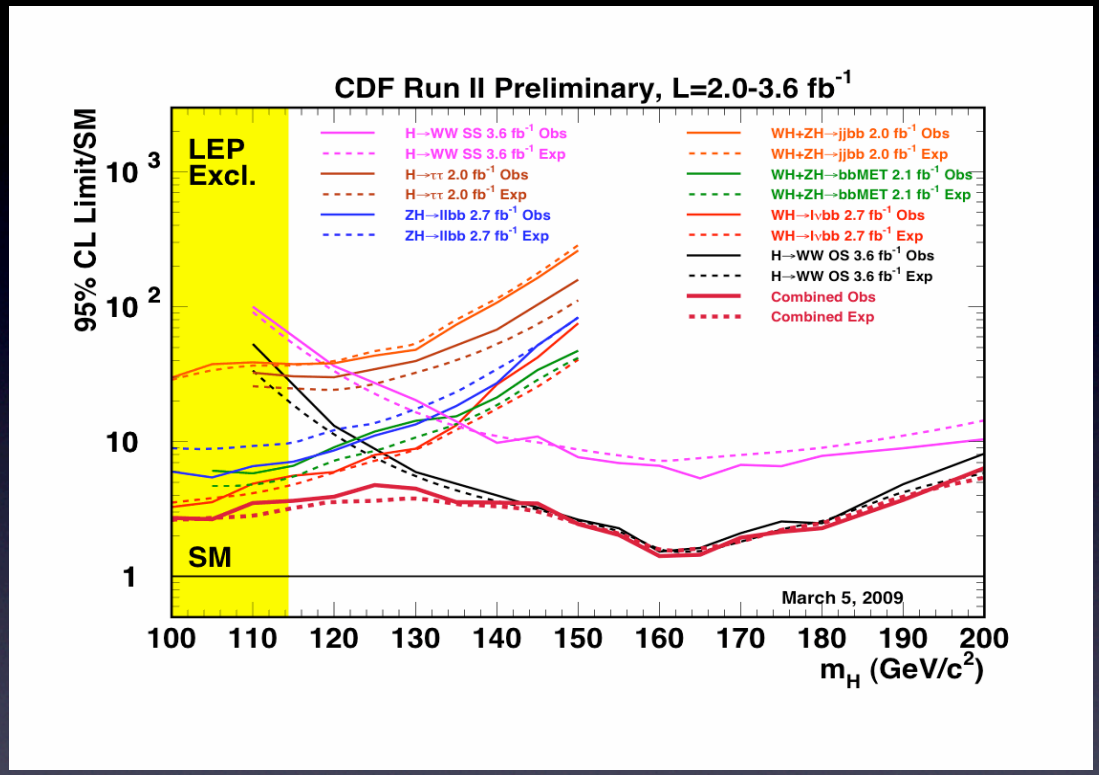


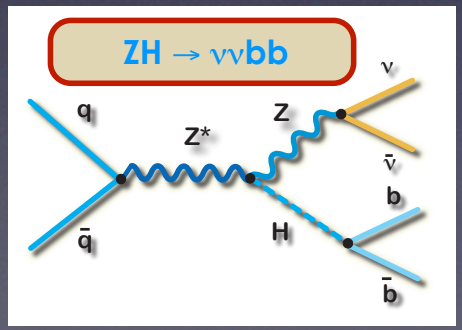
HIGGS

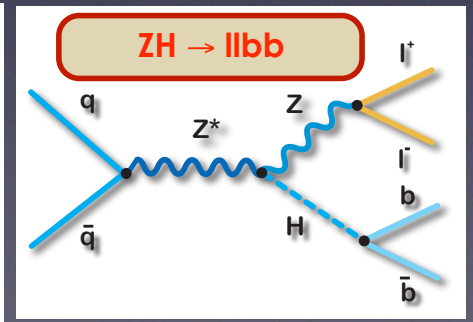
SM Higgs exclusion by CDF

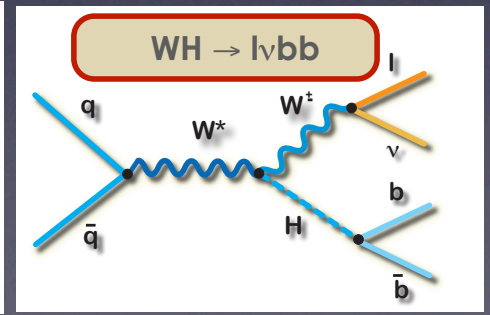


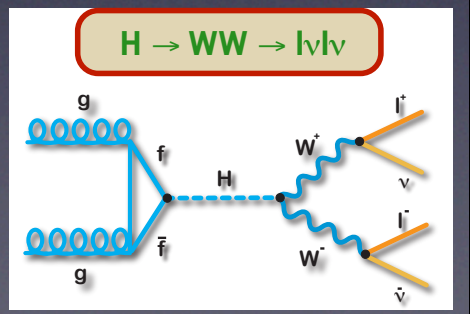
Exclusion Decomposition



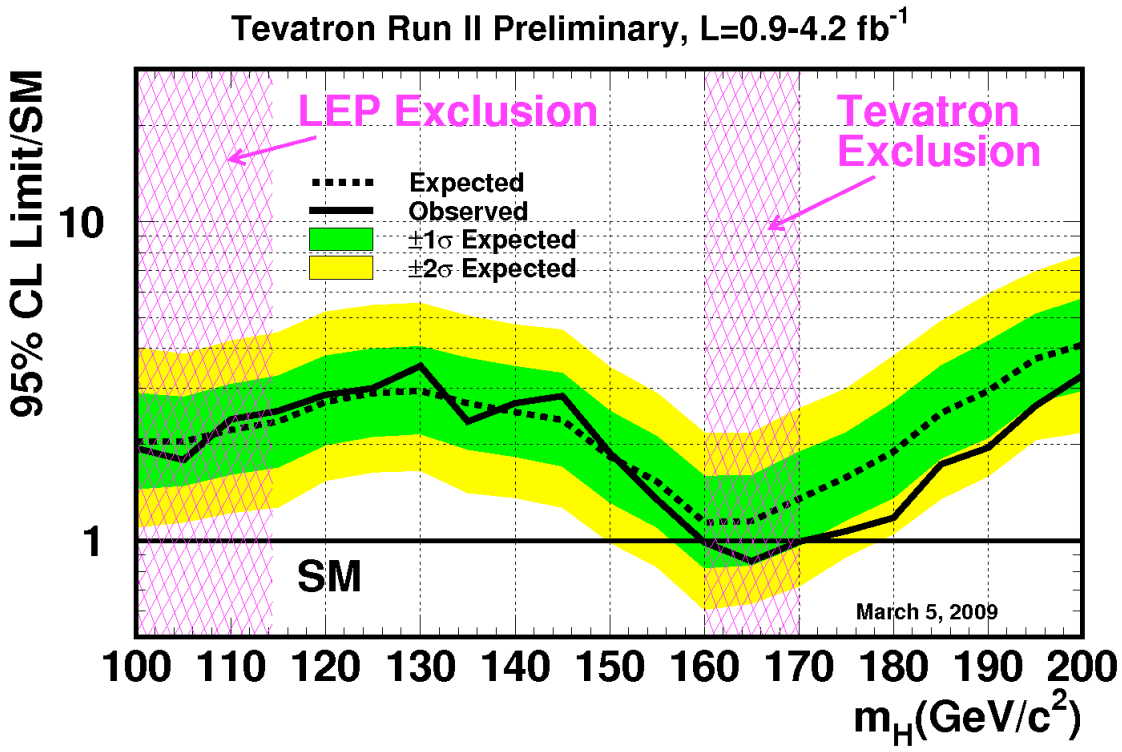






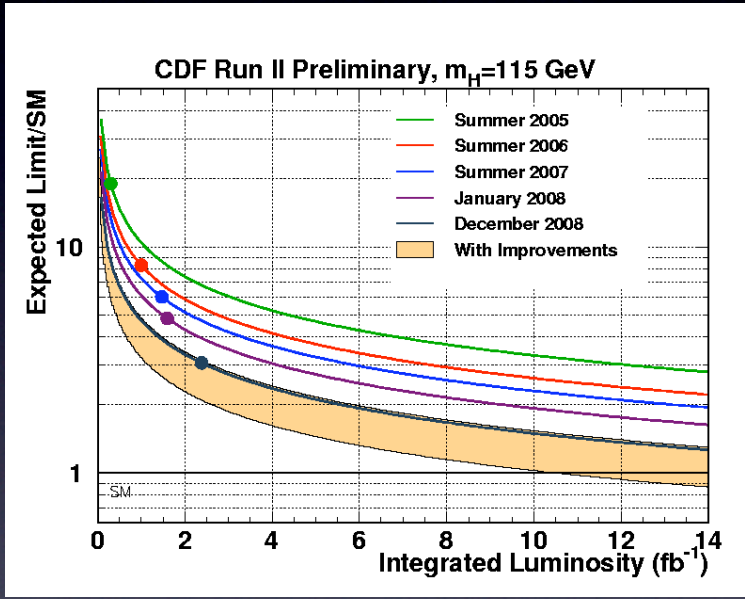


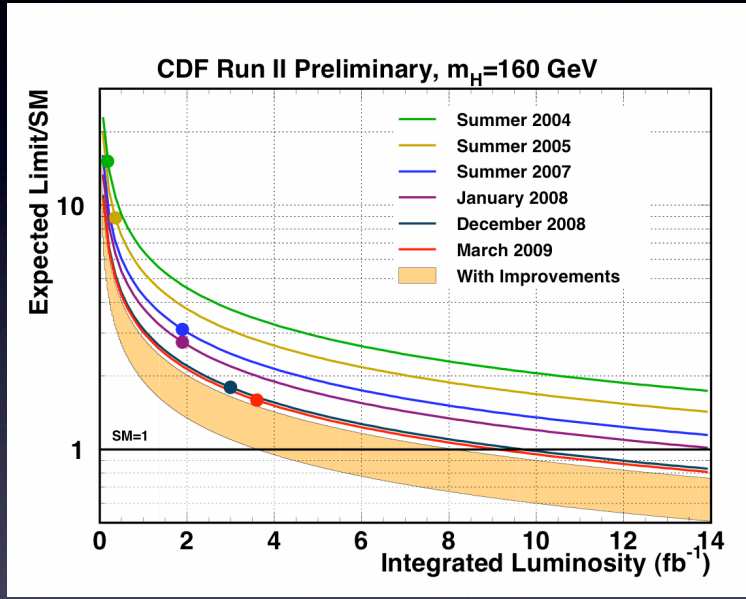
CDF-D0 Combined Exclusion



160 GeV < M_H < 170 GeV is excluded at 95% CL !

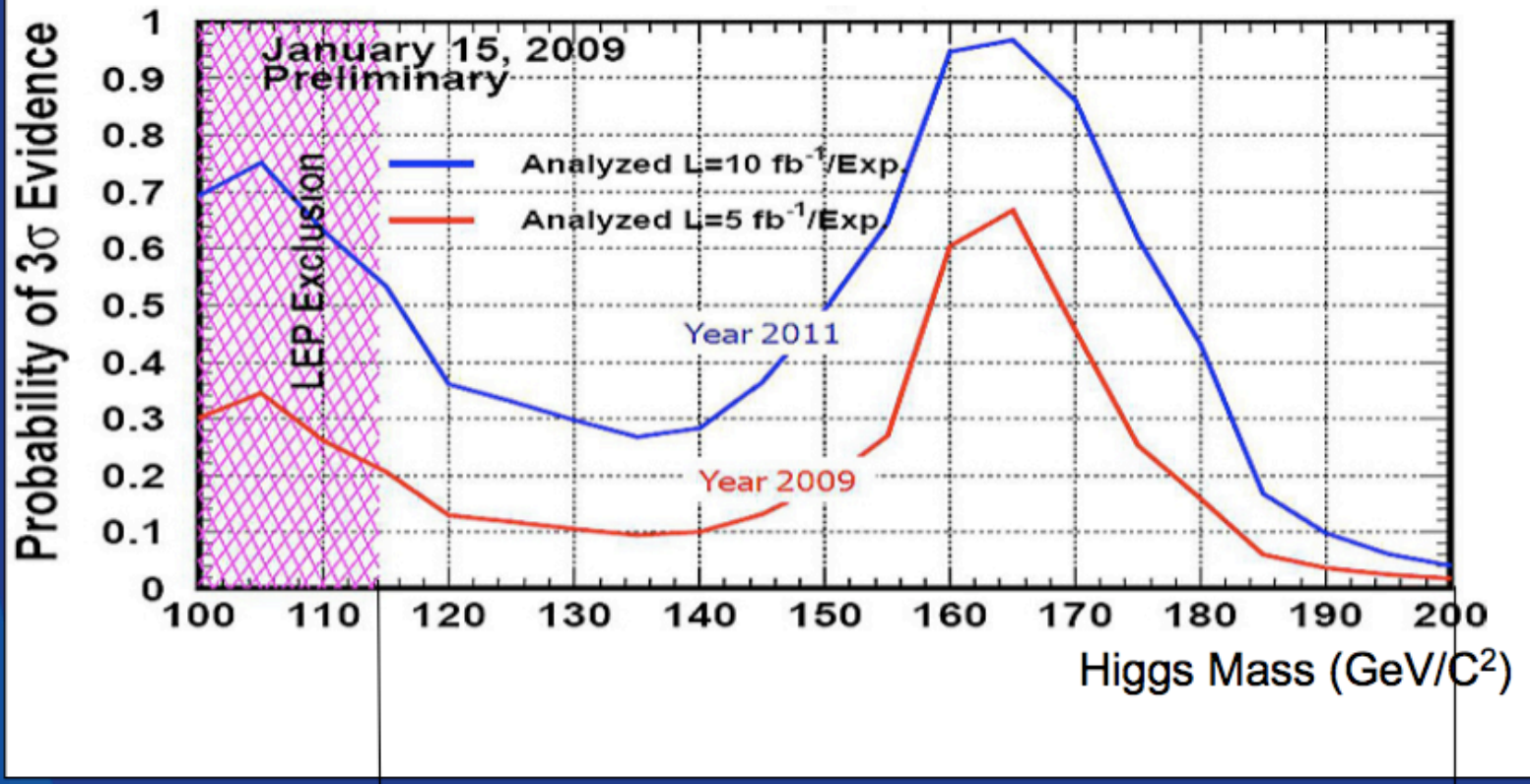
SM Higgs Limit Projections

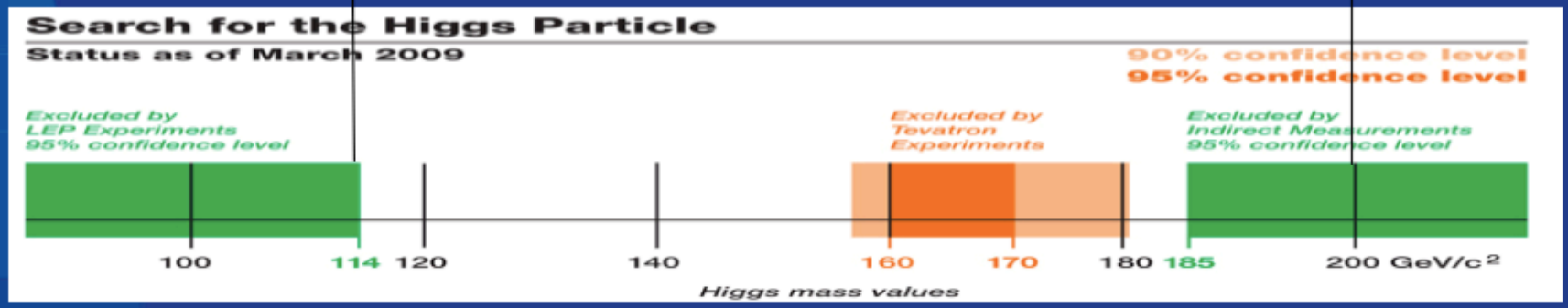




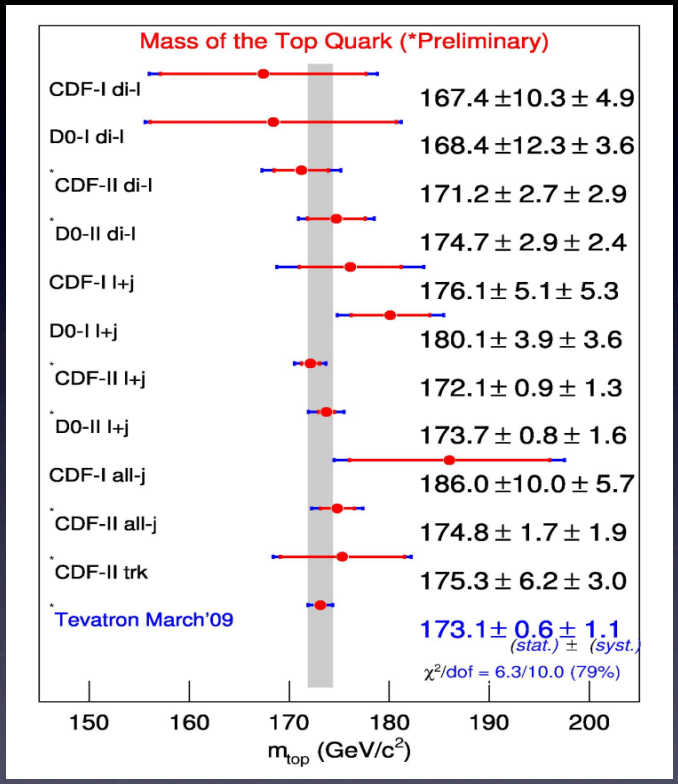
with 10/fb both experiments could reach SM cross section down to 115 GeV

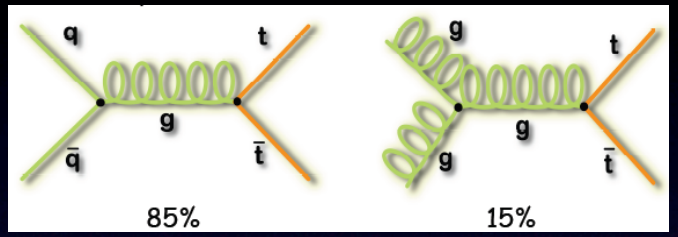
Sensitivity Projection (Region favored by M_{top}, M_W, … meas.s)

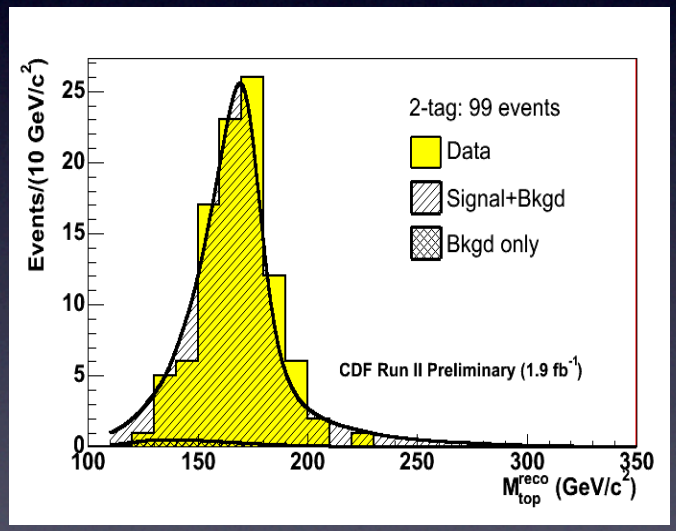




Top Mass

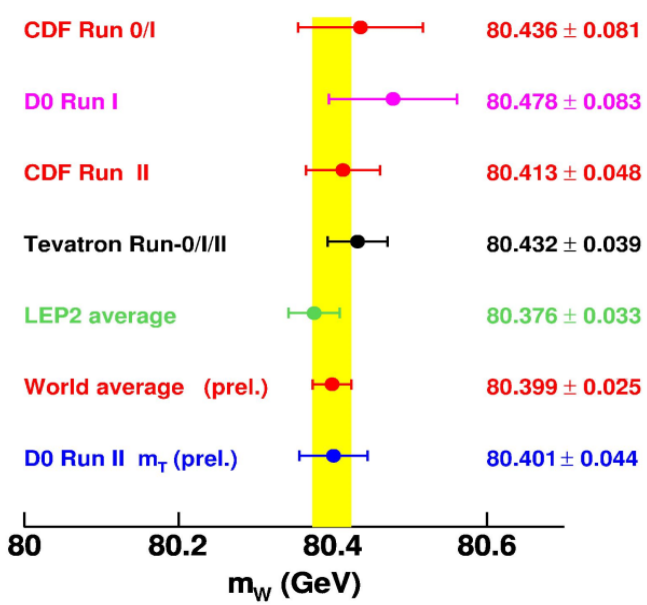






M_{top} = 173.1 ± 0.6 (stat) ± 1.1 (syst) GeV/c^2

W mass



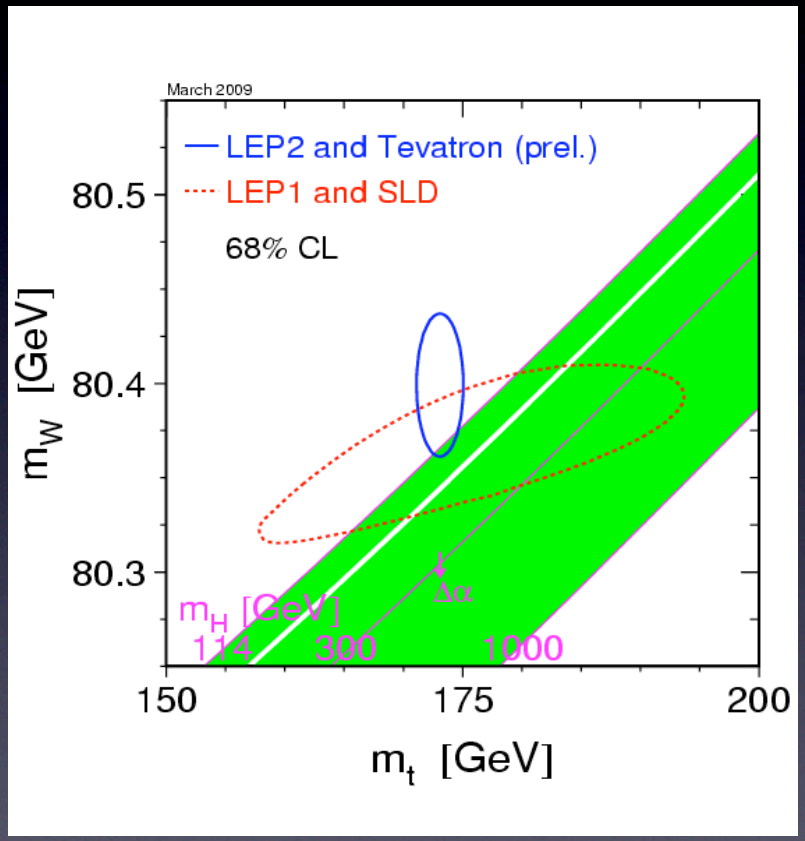
M_W = 80413±48 MeV (CDF, 0.3 fb^{-1})

= 80401±44 MeV (DØ, 1 fb^{-1})

Γ_W = 2032±73 MeV (CDF)

world's most precise single measurements!

Precision => Higgs Constraints



Expected now with all constraints :

$M_H = 90\ ^{+36}_{-27}$ GeV

$M_H < 163$ GeV @ 95 % CL

With 10 fb^{-1}

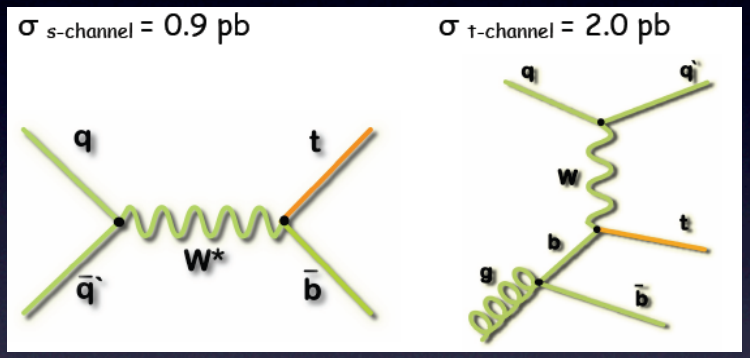
If dMw=15 MeV and dMtop=1 GeV
[for Mw= 80.400] expect

$M_H = 71 + 24 - 19$ GeV

$M_H < 117$ GeV @ 95% CL !

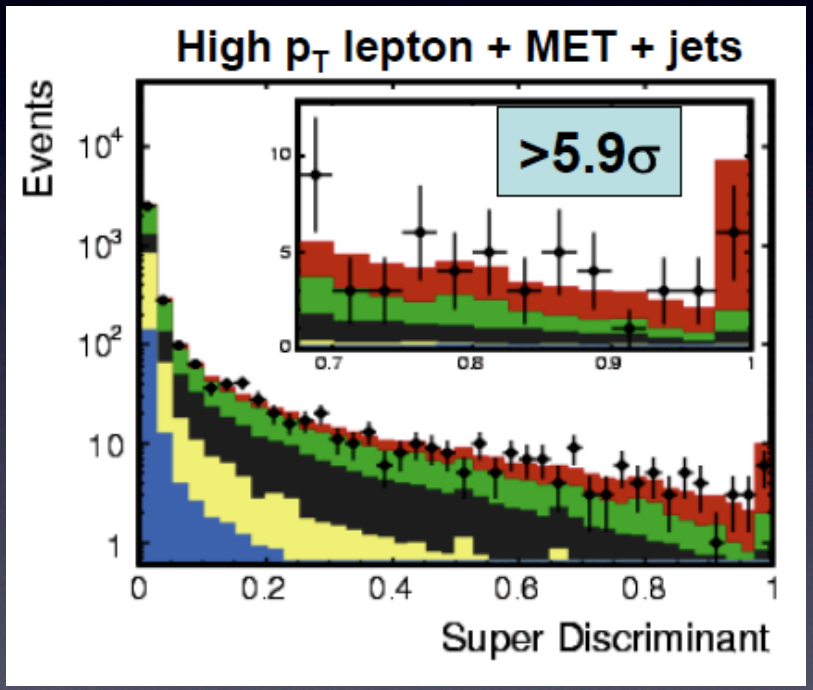
Single Top Observation

March 9, 2009



DØ : $\sigma_s + \sigma_t = 3.94 \pm 0.88$ pb

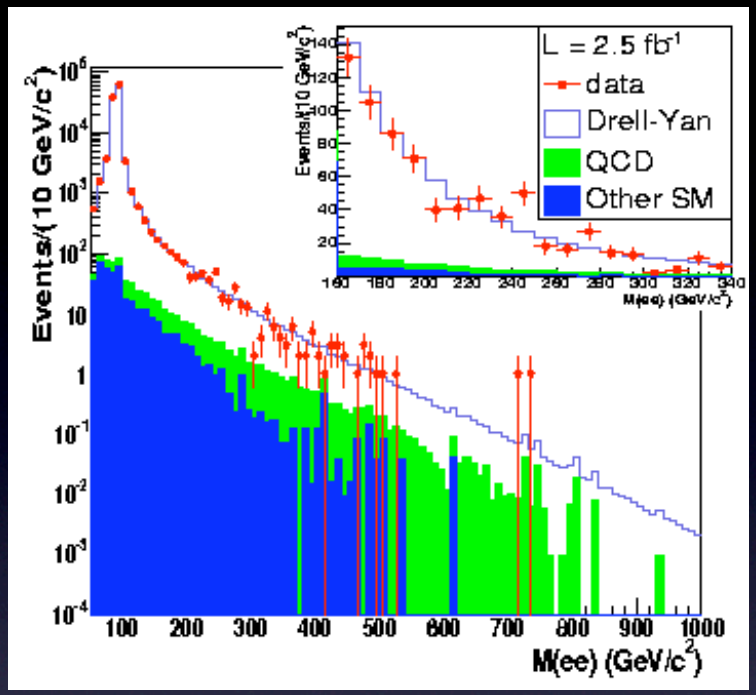
CDF: $\sigma_s + \sigma_t = 2.3^{+0.6}_{-0.5}$ pb

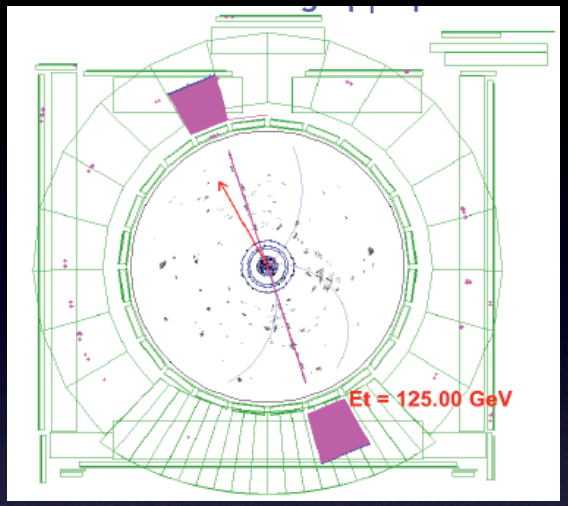


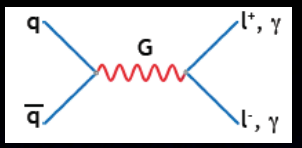
final state is very similar to WH

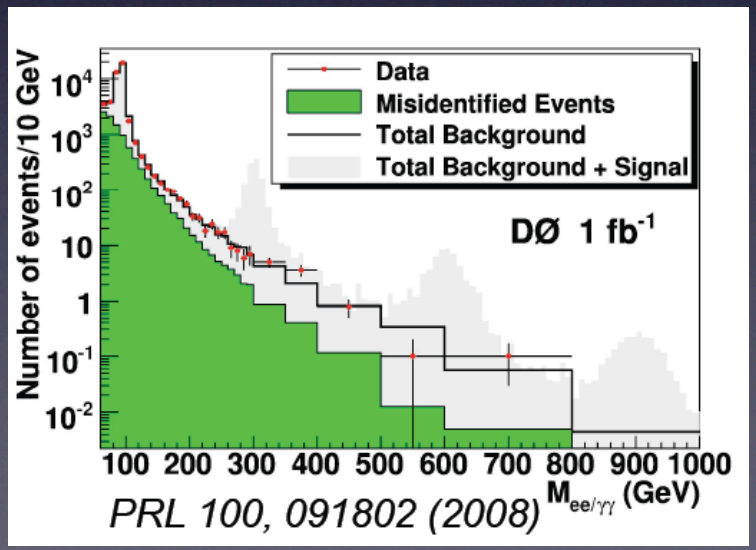
EXOTICS

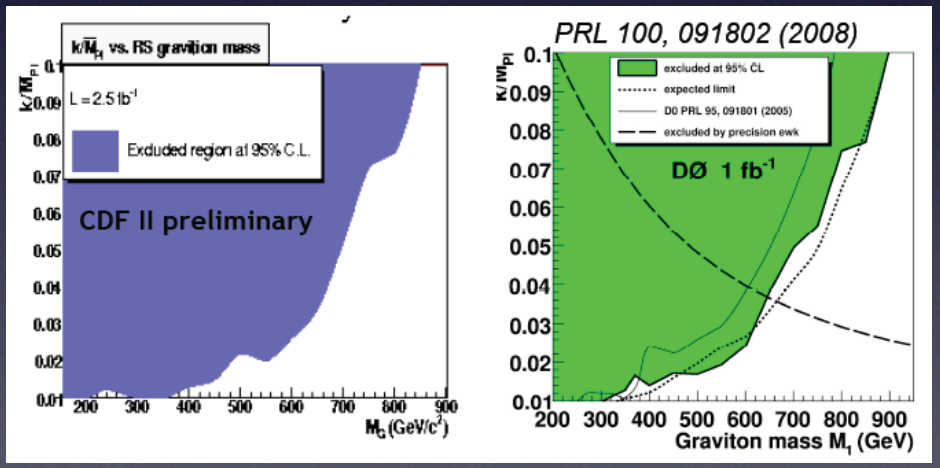
Search for High Mass e^+e^- Resonances











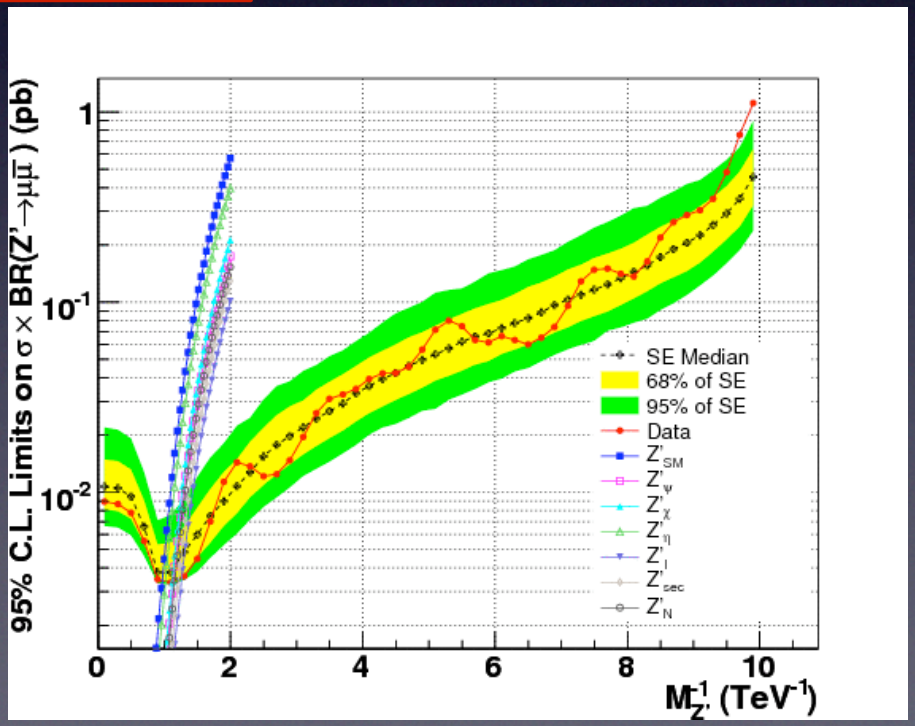
- CDF (DØ) exclude RS graviton with mass below 850 **(900)** GeV/c^2 for k/MPl=0.1

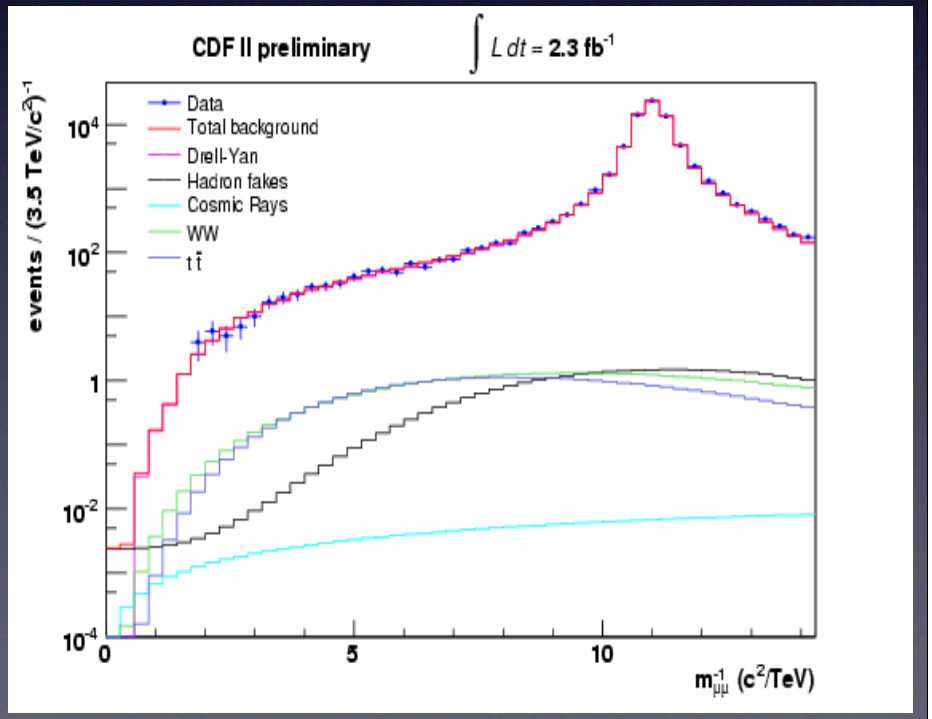
Di-muon Resonances

Z' model	Z' mass limit
Z'_I	789
Z'_{sec}	821
Z'_N	861
Z'_ψ	878
Z'_χ	892
Z'_η	982
Z'_{SM}	1030

For the first time beyond one TeV for SM-Z'!

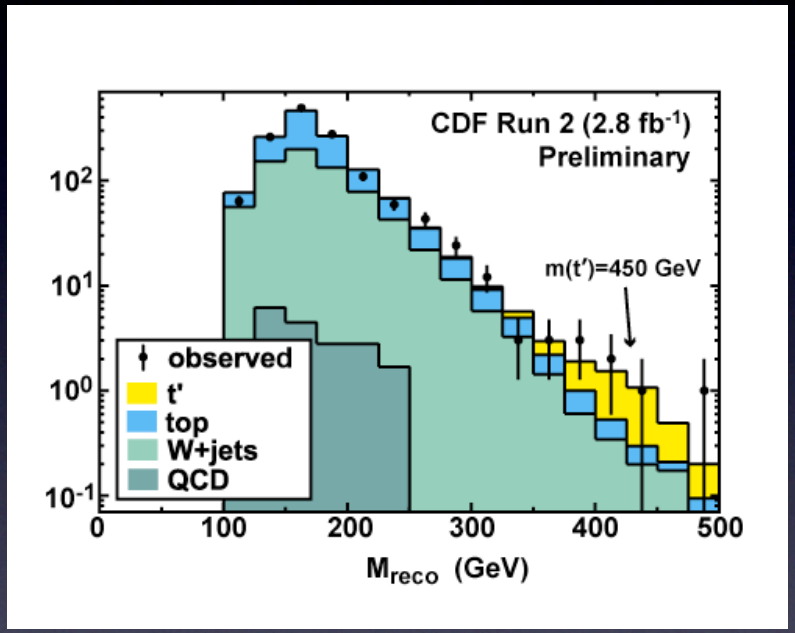
- Search in $1/m_{\mu\mu}$ in which detector resolution is ~const:
- 17% inverse mass resolution at 1 TeV

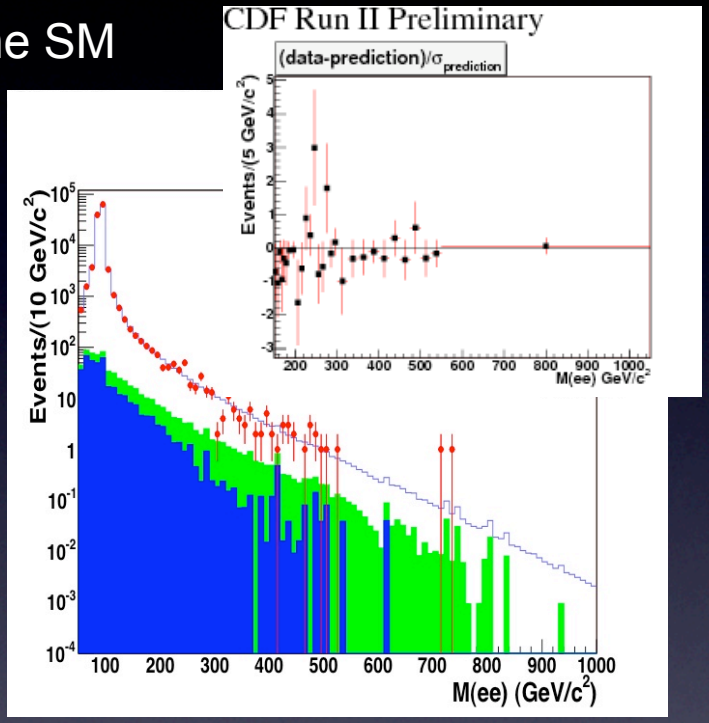




Discovery Watch

- Several results show discrepancies with the SM





2.5σ effects

- Are these just statistical fluctuations or hints of new physics?

Multimuon Analyses

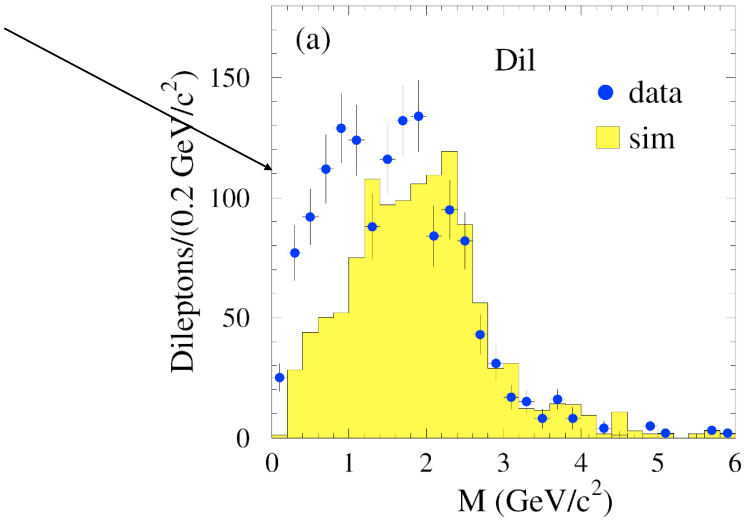
arXiv:0810.5357 [hep-ex]

Motivated by three long-standing discrepancies dating back to Tevatron Run I:

1. **$\sigma(pp \to b\bar{b}X)$ larger than expected from NLO QCD**
2. **Time-integrated mixing measured at Tevatron larger than LEP average**

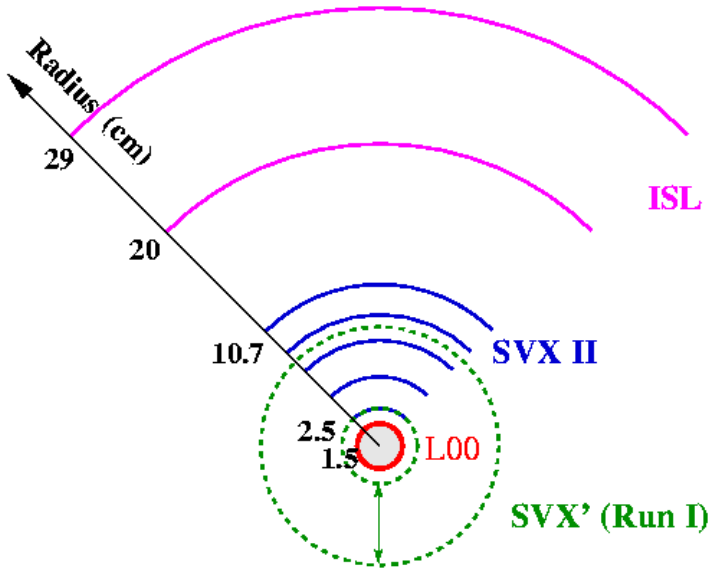
$$\bar{\chi} = \frac{\Gamma\left(B^0 \to \bar{B}^0 \to l^+ X\right)}{\Gamma\left(B \to l^{\pm} X\right)} = \frac{\text{"same sign"}}{\text{"total"}}, \quad B^0 = B_d^0 \text{ or } B_s^0$$

3. **low mass di-lepton spectrum inconsistent with expectations from heavy flavor.**

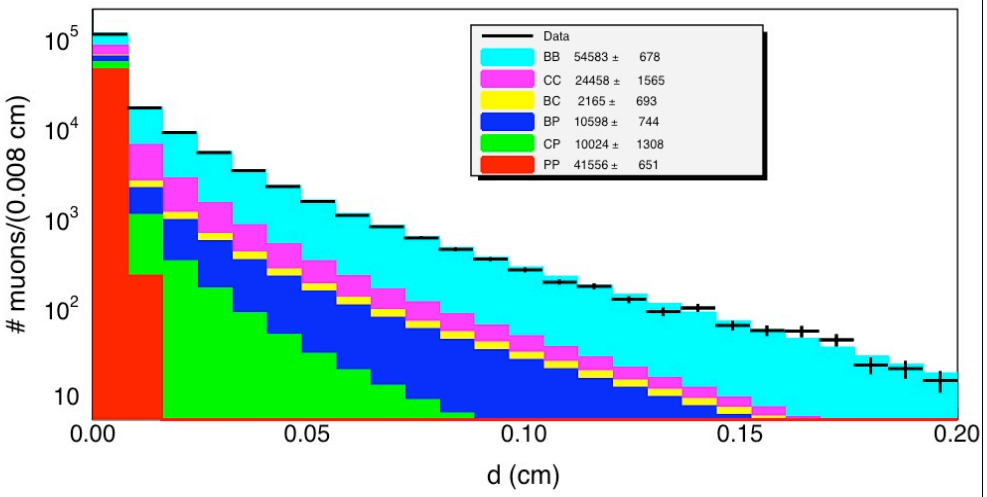


First, re-measure $\sigma(pp \to b\bar{b}X)$

- PRD 77, 072004 (2008)
- Strategy
  - Select dimuon events enriched in $b \to \mu$, $\bar{b} \to \mu$
  - Require our highest tracking precision to separate out prompt and charm backgrounds.
  - Fit muon impact parameters to separate contributions
- Sample
  - Well modeled by simulation
  - High purity: ~40% $b\bar{b}$
- Result
  - Measurement accuracy 9%
  - Good agreement with theory

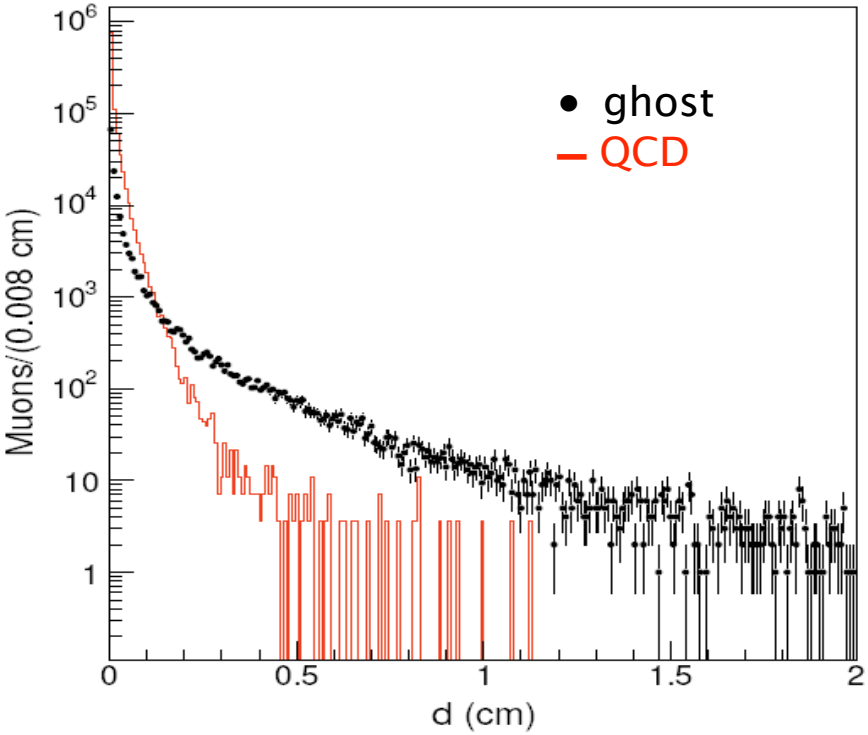


Require muons have hits on innermost silicon layers (R=1.5cm)



Next, investigate "other" dimuons

- observe many more events rejected by the tight selection than expected.
  - implies more background than expected.
  - Investigate this background. Much of it was not removed because it appears at large impact parameter!
- QCD sources (including heavy flavor) of dimuons have d_0<0.5cm
- "Ghost" events have much larger impact parameter!



Ghost sources

The rate of muons in the ghost sample is four times higher than the expectation.

Several known sources have been evaluated:

- Hadrons faking muons
- decay-in-flight of $K^{\pm}$, $\pi^{\pm}$, K_S, Λ, etc.
- Interactions in detector material

- **At this point, these sources do not seem to explain the entire sample.**
  - We are in a region of parameter space that is very challenging and largely uninvestigated.
- **We have chosen to publish the current results to report what we have learned.**
  - We state that we do not understand the source of these events.
  - We do not claim that the source of the events is beyond the standard model.
- **Regardless of their source, this sample of events**
  - has not been quantified before
  - very likely plays a role in the anomalies listed previously

- **The presence of ghost events is not confirmed by D0:**

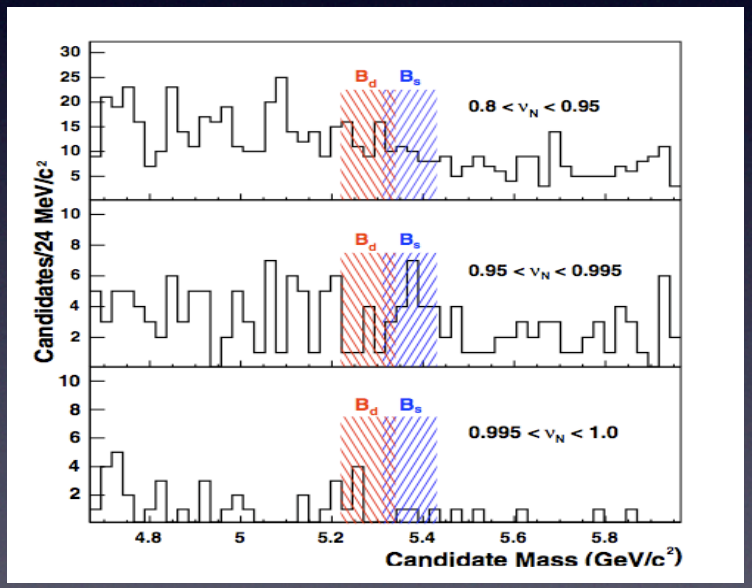
http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B57/B57.pdf

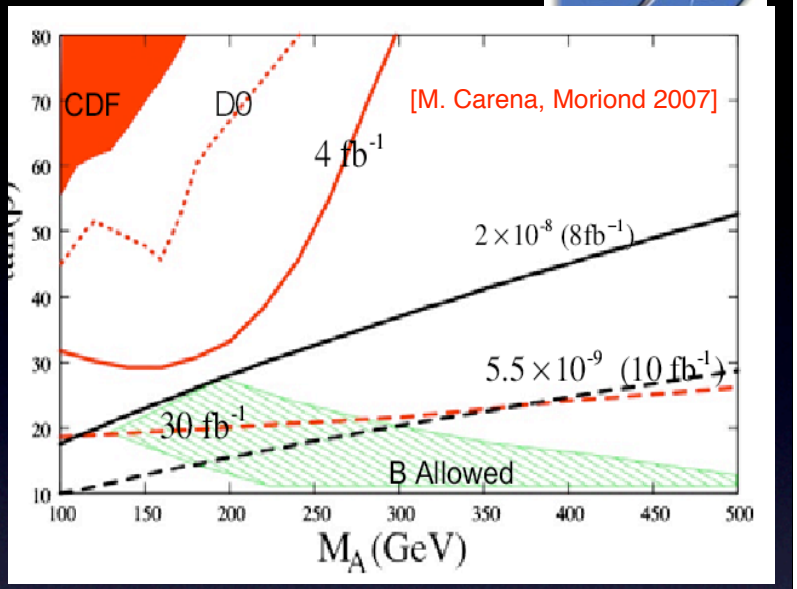
RARE DECAYS

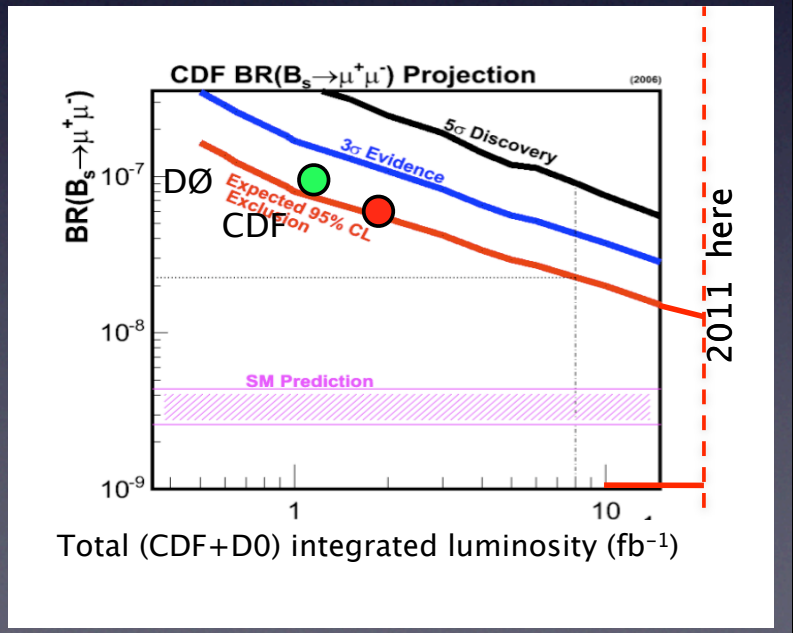
$B_s \rightarrow \mu^+\mu^-$

Limit 90% (95%) × 10^8	$B^0_s \rightarrow \mu\mu$	$B^0_d \rightarrow \mu\mu$
BaBar [PRD 77, 032007 (2008)]	n/a	5.2
DØ	7.5 (9.3)	n/a
CDF [PRL 100, 101802 (2008)]	4.7 (5.8)	1.5 (1.8)

- Already at ~10*SM with 2/fb
- Plenty of NP models already excluded



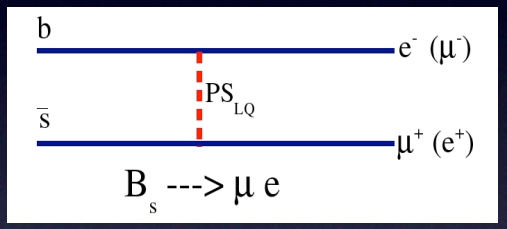


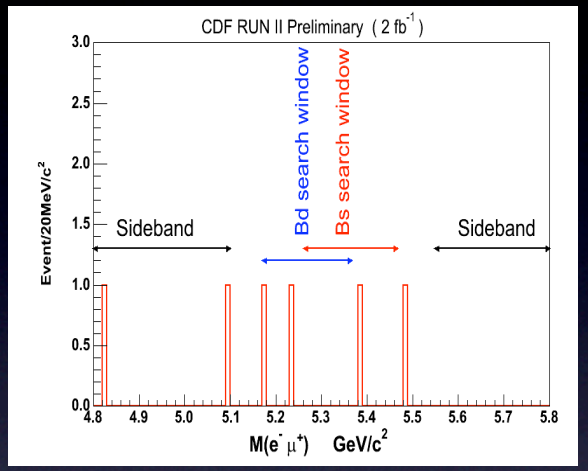


- No improvements assumed
- <1×10^{-8} (3×SM) at 10/fb per experiment

$B_{d,s} \rightarrow e^+\mu^-, e^+e^-$

- SM prediction very small < 1.0×10^{-15}
- Larger BRs in some NP models (e.g. Leptoquarks)



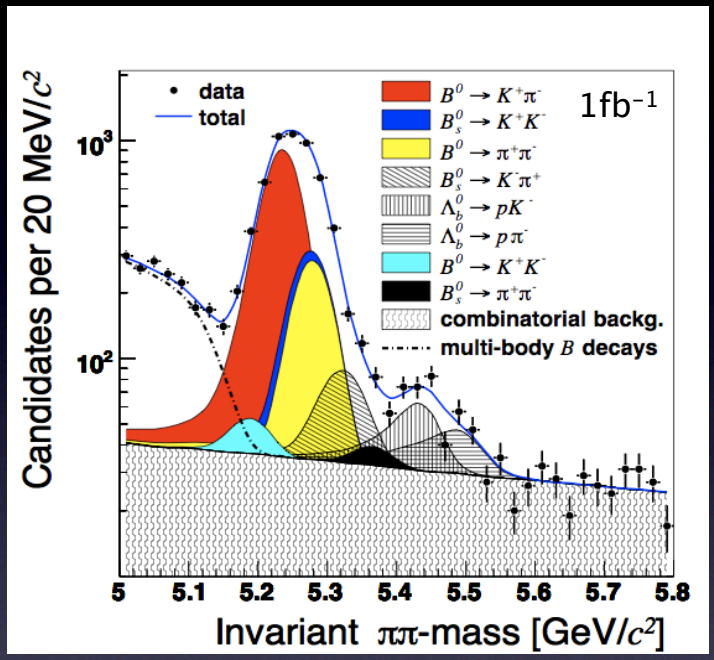


All measurements represent the current world best limits!

Channel	CDF Run II preliminary $(2fb^{-1})$ (@ 90(95)% C.L.)	BaBar (@ 90% C.L.)
$Br(B_s^0 \rightarrow e^+\mu^-)$	$< 2.0(2.6) \times 10^{-7}$	-
$M_{LQ}(B_s^0)$	$> 47.7(44.6)$ TeV/c^2	-
$Br(B_d^0 \rightarrow e^+\mu^-)$	$< 6.4(7.9) \times 10^{-8}$	$< 9.2 \times 10^{-8}$
$M_{LQ}(B_d^0)$	$> 58.6(55.7)$ TeV/c^2	> 53.1 TeV/c^2
$Br(B_s^0 \rightarrow e^+e^-)$	$< 2.8(3.7) \times 10^{-7}$	-
$Br(B_d^0 \rightarrow e^+e^-)$	$< 8.3(10.6) \times 10^{-8}$	$< 1.13 \times 10^{-7}$

FLAVOR PHYSICS

$B^0_{(s)} \rightarrow h^+h^-$



about 6000 events in 1 fb^{-1}

Possible precisions with 10 fb^{-1}

CDF with its trigger on secondary vertices is a serious competitor to the B factories

- CDF has access B^0, B^0_s e Λ_b
- Direct A_{CP} $B^0 \rightarrow K^+\pi^-$ was measured with precision similar to B factories
- Possible observation of direct A_{CP} in B^0_s ?

{ <1% on direct A_{CP} in $B^0 \rightarrow K^+\pi^-$

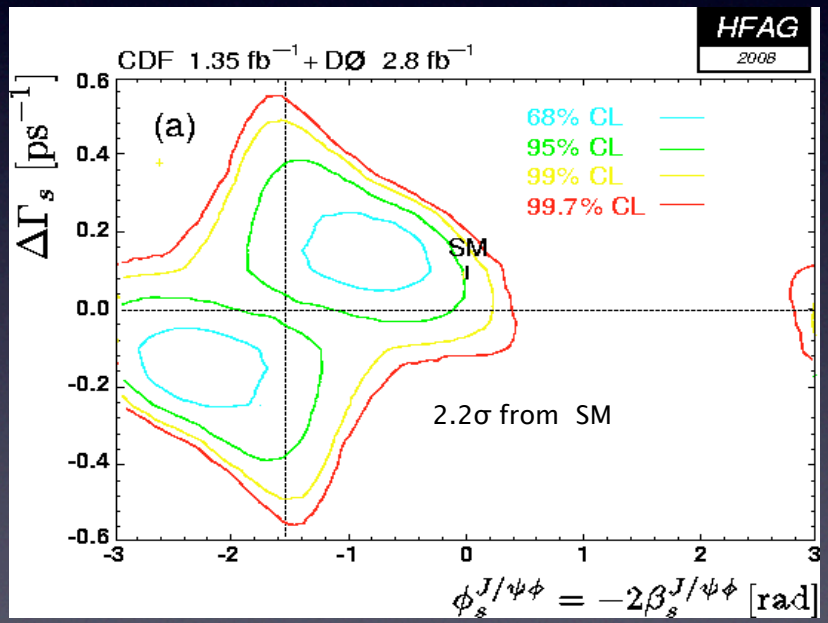
<8% on direct A_{CP} in $B^0_s \rightarrow K^-\pi^+$

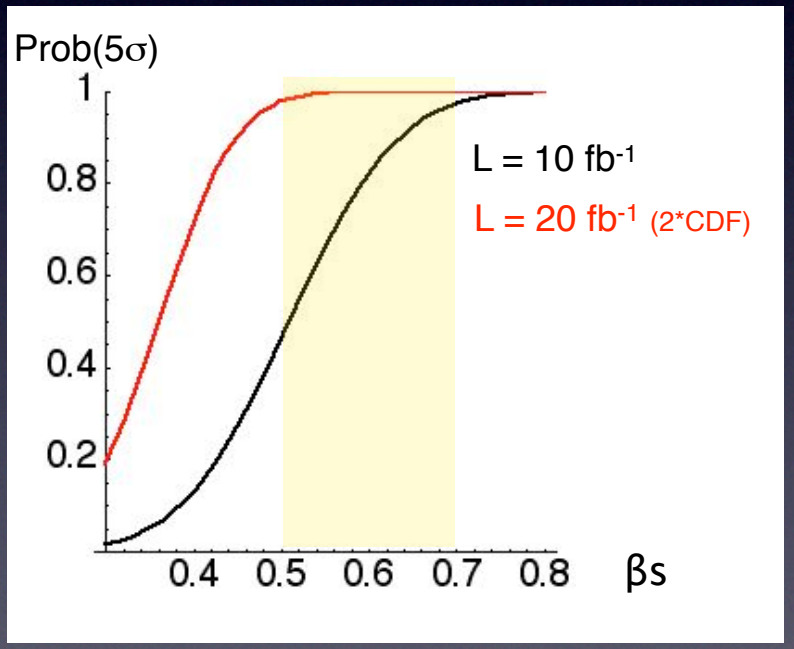
(SM predicts large value 30-40%)

B^0_s mixing phase: $B^0_s \rightarrow J/\psi\,\varphi$

- B^0_s sector unique to Tevatron and fully unexplored
- Δm_s excluded large NP magnitude in B^0_s mixing (2006)
- NP phase still unconstrained
- Probe it through time-evolution of $B^0_s \rightarrow J/\psi\,\varphi$ decays

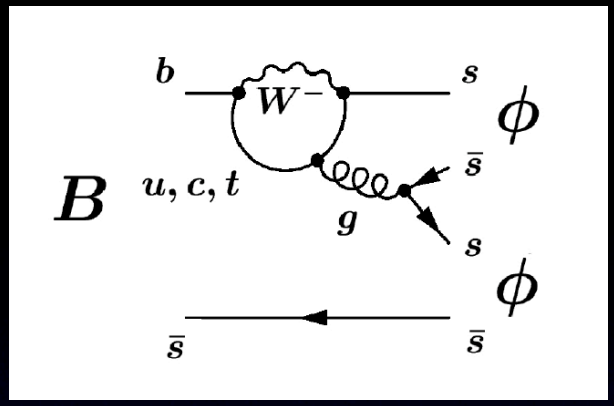
- CDF and DØ observe a consistent fluctuation (same direction, same significance)
- Current average $\beta_s = 0.4$





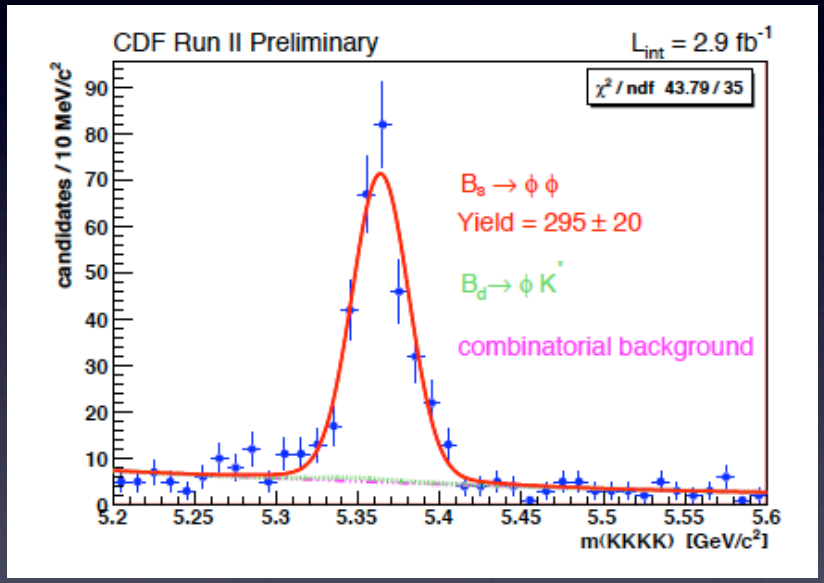
- NP expectations $\beta_s = 0.5 \div 0.7$
  [Hou at al., Phys.Rev.D76:016004,2007]

If NP phase is large (>0.5) Tevatron will observe it

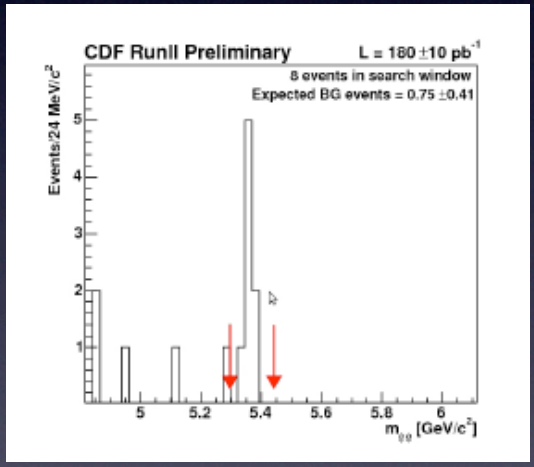


$B_s \rightarrow \varphi\varphi \rightarrow K^+K^-K^+K^-$

CDF 2009 ~ 300 events



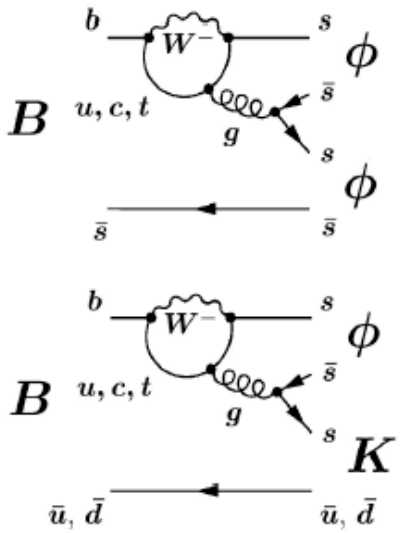
CDF 2005 - 8 events

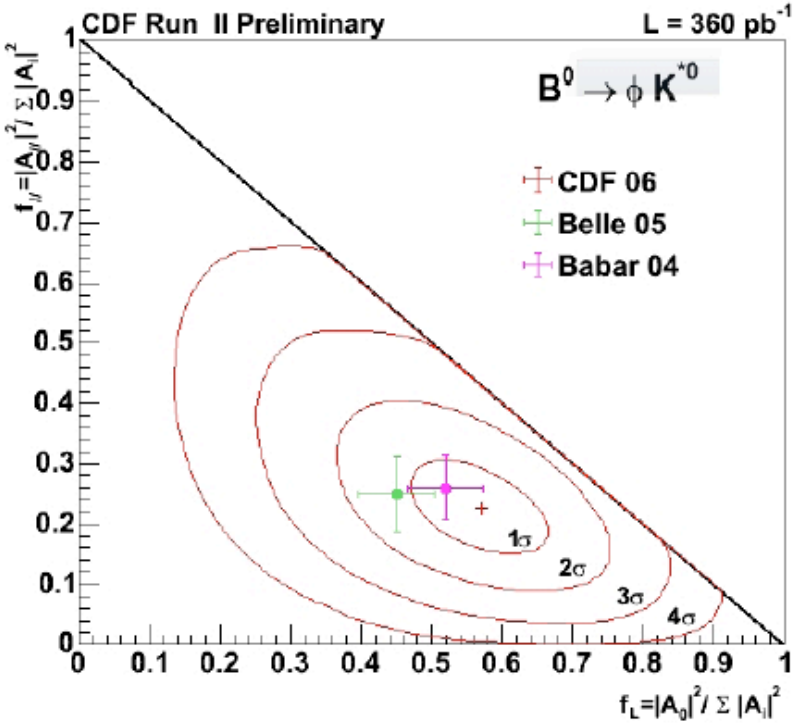


$$BR(B_s \longrightarrow \phi\phi) = [1.4 \pm 0.6(stat) \pm 0.6(syst)] \cdot 10^{-5}$$

$B_s \rightarrow \varphi\varphi \rightarrow K^+K^-K^+K^-$

- First polarization measurement, comparing with $B_d \longrightarrow \phi K^*$



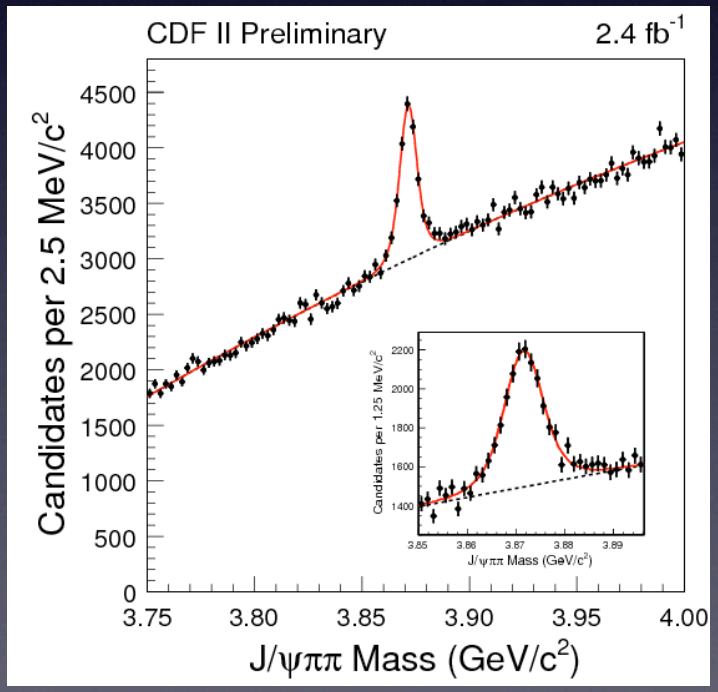


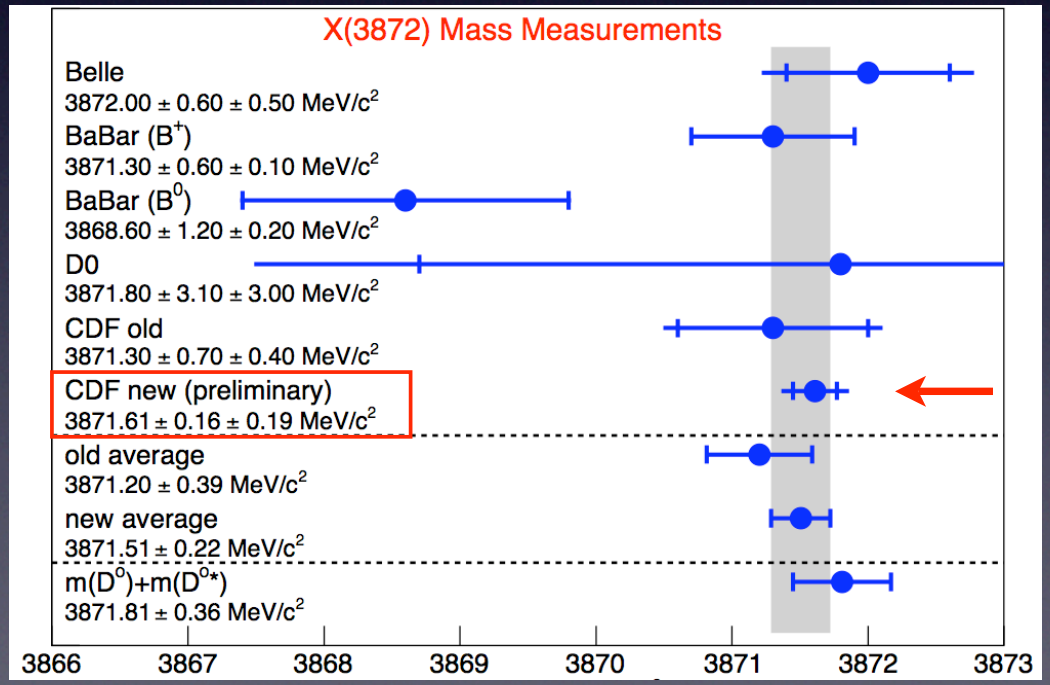
NEW STATES

Mass Measurement of the X(3872) State

CDF: m = 3871.61 ± 0.16 (stat) ± 0.19 (syst) MeV/c^2

- This is the most precise measurement to date
- The value is below the D*D threshold, but within uncertainties. The explanation of the X(3872) as a bound D*D system is therefore still an option



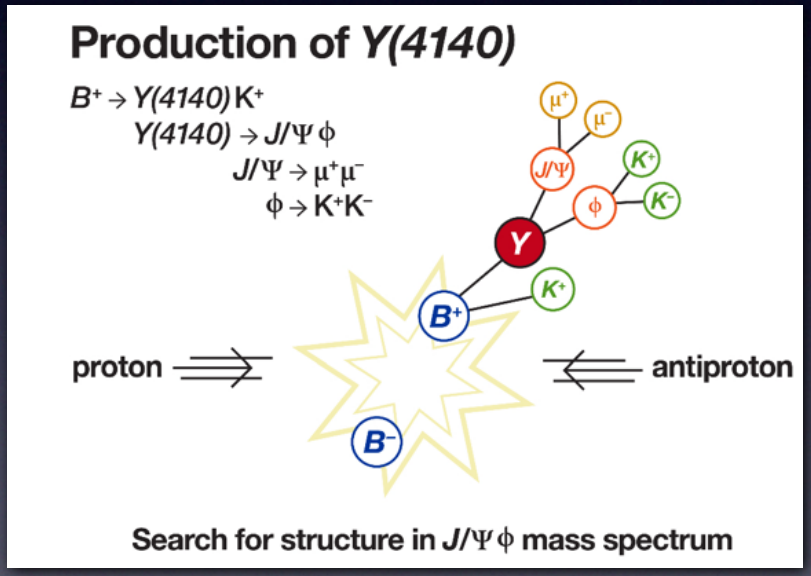


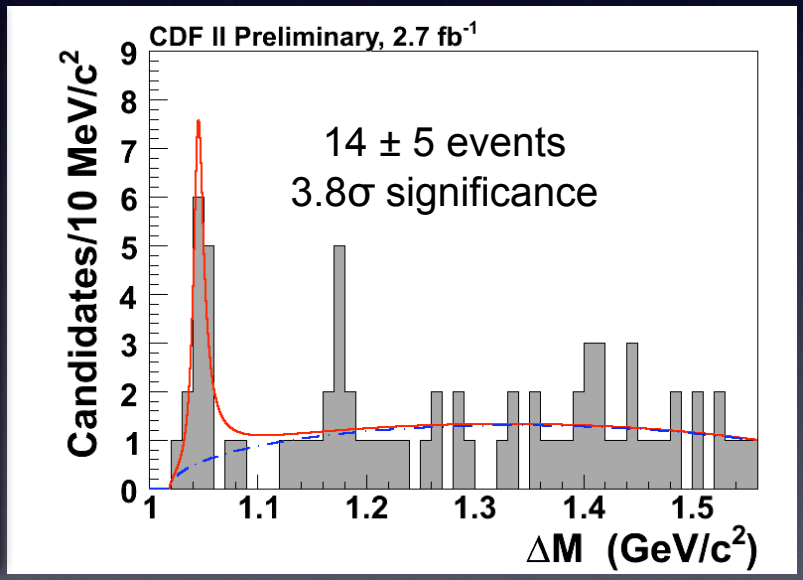
Evidence for Y(4140)

Narrow near-threshold structure in the J/ψ φ mass spectrum in $B^+ \rightarrow J/\psi\, \varphi\, K^+$

arXiv:0903.2229

$B^+ \rightarrow Y(4140)K^+$; $Y(4140) \rightarrow J/\psi\, \varphi$; $J/\Psi \rightarrow \mu^+\mu^-$; $\varphi \rightarrow K^+ K^-$



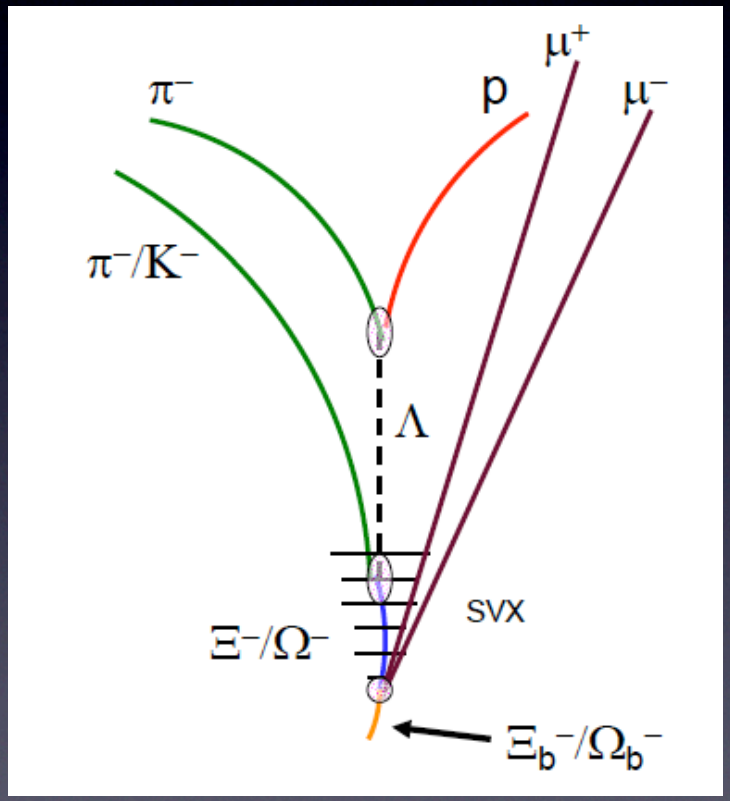


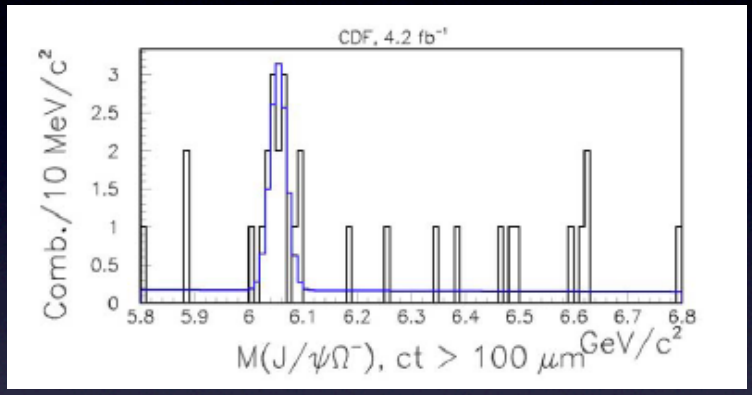
we measure:

- m = 4143.0 ± 2.9 (stat.) ± 1.2(syst.) MeV/c2
- Γ = 11.7 + 8.3 - 5.0 (stat.) ± 3.7(syst.) MeV/c2

Observation of the Ω_b^-

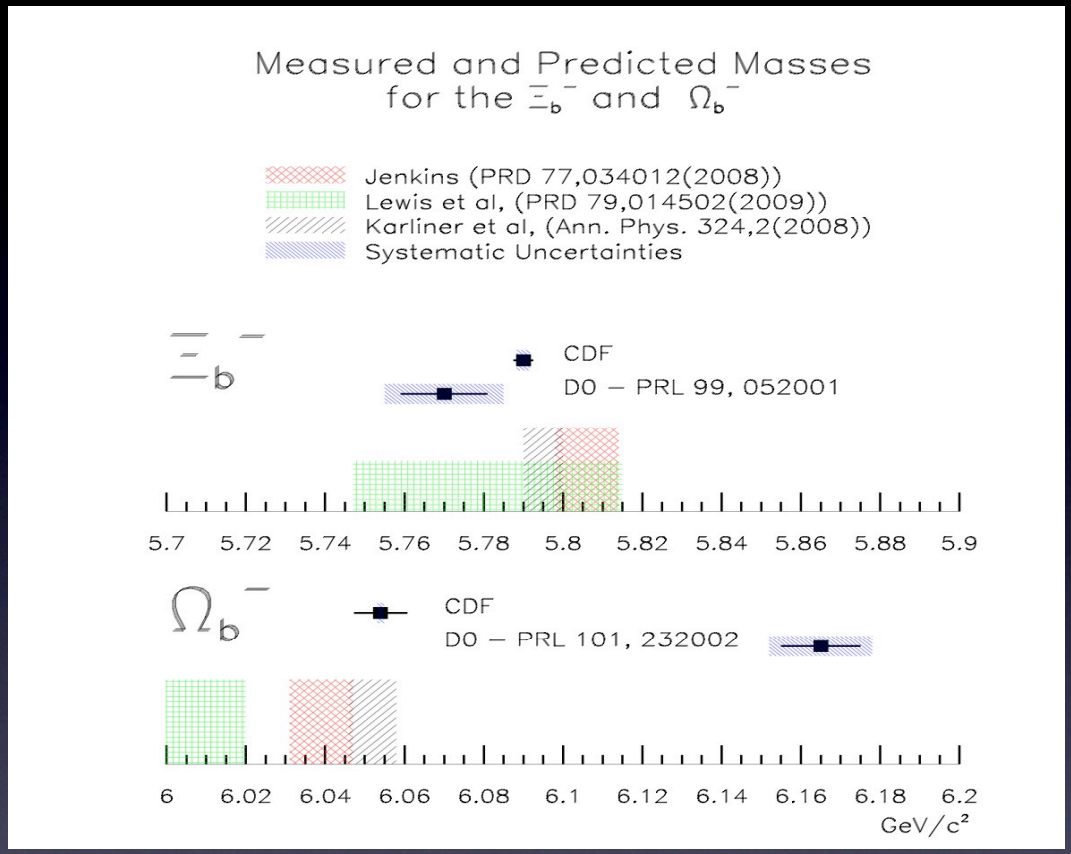
arXiv:0905.3123





- Interpreted as $P(\chi^2)$ with 3 d.o.f., = 4.0×10^{-8}, => 5.5σ
- Fit results:
  - Mass: 6055.5±6.6 MeV/c^2
  - $c\tau_0$: 338±100 μm
  - Yield: 18±5

Ω_b^- Mass Measurements Compared



- D0 finds
  - $M(\Omega_b^-)=6165 \pm 10(stat.) \pm 13(syst.)$ MeV/c²
    - PRL **101**, 232002(2008)
- CDF finds
  - $M(\Omega_b^-)= 6054.4 \pm 6.8(stat.) \pm 0.9(syst.)$ MeV/c²

Final Remarks

- Scientific production of CDF and DZero is at its peak
- The Tevatron era is far from being over
- Maybe the best is yet to come